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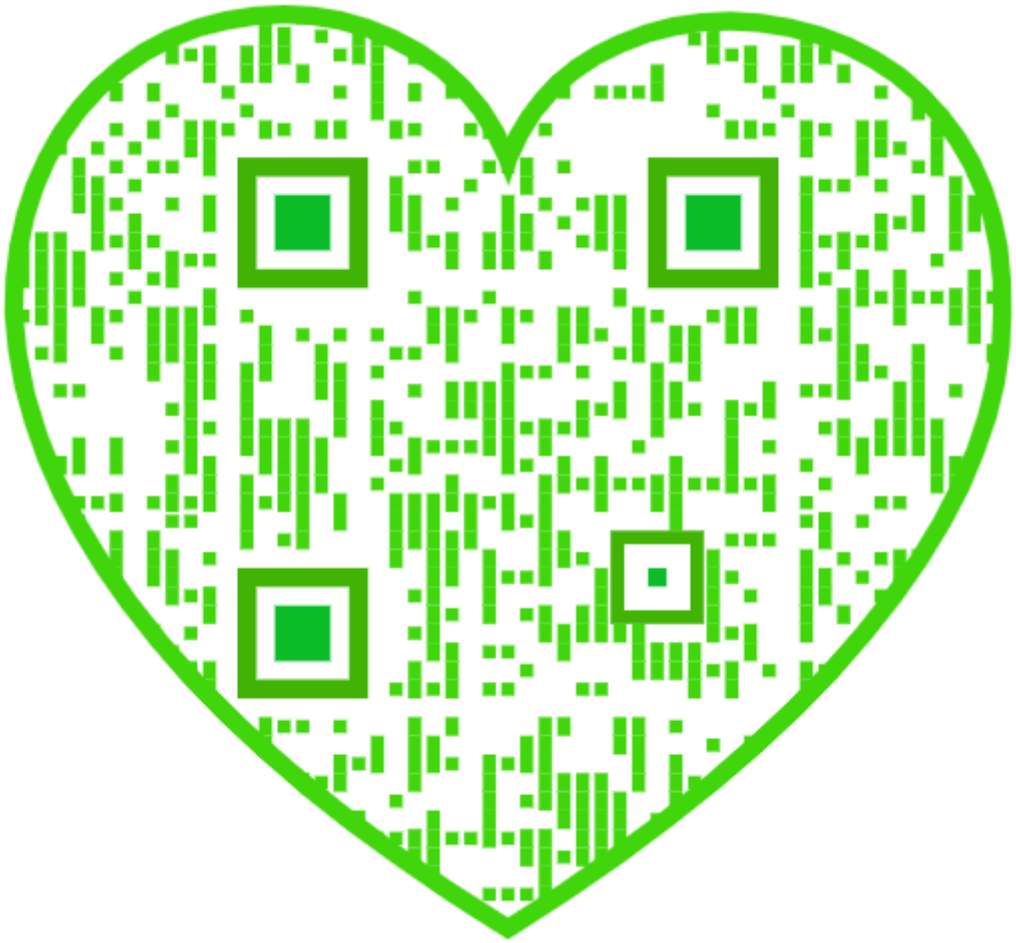

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J. Avery Shepherd

AN INTRODUCTION

TO

J. Avery Shepherd

BOTANY.

BY

JOHN LINDLEY, PH. D. F.R.S.,
PROFESSOR OF BOTANY IN UNIVERSITY COLLEGE, LONDON, ETC.

WITH SIX COPPER-PLATES AND NUMEROUS WOOD-ENGRAVINGS.

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INTRODUCTION

TO

BOTANY.

BOOK I.

ORGANOGRAPHY; OR, OF THE STRUCTURE OF PLANTS.

CHAPTER II.

OF THE COMPOUND ORGANS IN FLOWERING PLANTS—*continued.*

14. Of the Fruit.

The *fruit* (*figs.* 136. to 168.) is the ovary or pistil arrived at maturity. But, although this is the sense in which the term is strictly applied, yet in practice it is extended to whatever is combined with the ovary when ripe. Thus the pine-apple fruit consists of a mass of bracts, calyxes, corollas, and ovaries; that of the nut, the acorn, and many others, of the superior dry calyx and ovary; that of the apple of a succulent superior calyx, corolla, and ovary; and that of the strawberry-blite of a succulent inferior calyx and dry ovary.

The fruit being the matured ovary, it should exhibit upon some part of its surface the traces of a style or stigma; and this mark will, in many cases, enable the student to distinguish minute fruits from seeds. Many fruits were formerly called *naked seeds*, such as those of Umbellifers, Labiates, and Borageworts, and the grain of corn; but now that attention has been paid to the gradual development of organs, such errors have been corrected. In cases where a trace of

the style cannot be discovered, anatomy will generally show whether a minute body is a seed or fruit, by the presence, in the latter case, of two separable and obviously organically distinct coatings to the nucleus of the seed; but in other cases, where the pericarp and the integuments of the seeds are combined in a single covering, and where no trace of style remains, as sometimes happens, nothing can be determined as to the exact nature of a given body without following it back in its growth to its young state. This, however, may be stated, that naked seeds, properly so called, are not known to exist, unless accidentally, in more than three or four orders in the whole vegetable kingdom; viz. in Conifers and Cycads, where the ovules also are naked, and in Peliosanthes Teta and Leontice, in which the ovules, originally enclosed in an ovary, uniformly rupture it at an early period after fertilisation, and subsequently continue naked until they become seeds.

Such being the case, it follows that all the laws of structure which exist in the ovary are equally to be expected in the fruit; and this fact renders a repetition in this place of the general laws of formation unnecessary. Nevertheless, as, in the course of the advance of the ovary to maturity, many changes often occur which contribute to conceal the real structure of the fruit, it is in all cases advisable, and in many absolutely necessary, to examine the ovary, in order to be certain of the exact construction of the fruit itself. These changes are caused by the abortion, non-development, obliteration, addition, or union of parts. Thus the three-celled six-ovuled ovary of the oak and the hazel becomes, by the non-development of two cells and five ovules, a fruit with one seed; the three-celled ovary of the cocoa-nut is converted into a one-celled fruit, by the obliteration of two cells and their ovules; and the two-celled ovary of some Pedaliads becomes many-celled, by a division and elongation of the placentæ. In Cathartocarpus Fistula a one-celled ovary changes into a fruit having each of its many seeds lodged in a separate cell, in consequence of the formation of numerous horizontal membranes which intercept the seeds. A still more extraordinary confusion of parts takes place in the fruit of the

pomegranate after the ovary is fertilised; and many other cases might be mentioned.

Every fruit consists of two principal parts, the *pericarp* and the *seed*, the latter being contained within the former. When the ovary is inferior, or coheres with the calyx, the latter and the pericarp are usually so completely united as to be inseparable and undistinguishable: in such cases it is usual to speak of the pericarp without reference to the calyx, as if no such union had taken place. Botanists call a fruit, the pericarp of which adheres to the calyx, an inferior fruit (*fructus inferus*); and that which does not adhere to the calyx, a superior fruit (*fructus superus*). But Desvaux has coined other words to express these ideas: a superior fruit he calls *autocarpic*; an inferior fruit, *heterocarpic*; terms unnecessary and unworthy of adoption.

Everything which in a ripe fruit is on the outside of the real integuments of the seed, except the aril, belongs to the pericarp. It consists of three different parts, the *epicarp*, the *sarcocarp*, and the *endocarp*; terms contrived by Richard, and useful in practice.

The *epicarp* is the external integument or skin; the *endocarp*, called *putamen* by Gærtner, the inner coat or shell; and the *sarcocarp*, the intermediate flesh. Thus, in the peach, the separable skin is the epicarp, the pulpy flesh the sarcocarp, and the stone the endocarp or putamen. In the apple and pear the epicarp is formed by the cuticle of the calyx, and the sarcocarp is confluent with the remainder of the calyx in one fleshy body.

The *pericarp* is extremely diversified in size and texture, varying from the dimension of a single line in length to the magnitude of two feet in diameter; and from the texture of a delicate membrane to the coarse fabric of wood itself, through various cartilaginous, coriaceous, bony, spongy, succulent, or fibrous gradations.

The *base* of the pericarp is the part where it unites with the peduncle; its *apex* is where the style was: hence the organic and apparent apices of the fruit are often very different, especially in such as have the style growing from

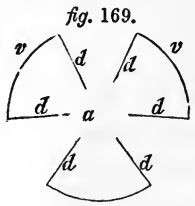
their sides, as in Rosaceæ and Chrysobalanaceæ, Labiatæ and Boraginaceæ.

When a fruit has arrived at maturity, its pericarp either continues perfectly closed, when it is *indehiscent*, as in the hazel nut; or separates regularly round its axis, either wholly or partially, into several pieces: the separation is called *dehiscence*, and such pieces *valves;* and the axis from which the valves separate, in those cases where there is a distinct axis, is called the *columella*.

When the dehiscence takes place through the dissepiments, it is said to be *septicidal;* when through the back of the cells, it is called *loculicidal;* if along the inner edge of a simple fruit it is called *sutural;* if the dissepiments are separated from the valves, the dehiscence is named *septifragal*.

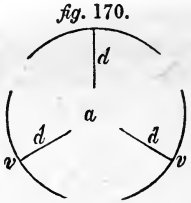
In *septicidal* dehiscence the dissepiments divide into two plates and form the sides of each valve, as in Rhododendron, Menziesia, &c. Formerly botanists said that in this sort of dehiscence the valves were alternate with the dissepiments, or that the valves had their margins turned inwards. This may be understood from *fig.* 169., which represents the

fig. 169.



relative position of parts in a transverse section of a fruit with septicidal dehiscence; *v* being the valves, *d* the dissepiments, and *a* the axis.

fig. 170.

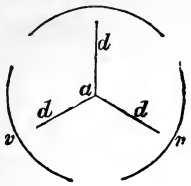


In *loculicidal* dehiscence the dissepiments form the middle of each valve, as in the lilac, or in the diagram 170.,

where the letters have the same value as above. In this it was formerly said that the dissepiments were opposite the valves.

In *septifragal* dehiscence the dissepiments adhere to the axis and separate from the valves, as in Convolvulus; or in the diagram 171., lettered as before.

fig. 171.



In *sutural* dehiscence there are no dissepiments, the fruit being composed of only one carpel, as the Pea.

Besides these regular forms of valvular dehiscence, there is a very anomalous mode which occurs in a very few plants, and is called *circumscissile*. This takes place by a transverse circular separation, as in Anagallis; in Jeffersonia it only takes place half round the fruit. In some cases, as in lomentaceous legumes, the transverse disarticulation may be supposed to have some relation to the pinnate leaves, whose modification, in those instances, forms the carpel. In other cases the explanation is far less obvious, and must be at least very different. Perhaps the best account of transverse dehiscence is that of Mr. Hincks, as reported in the *Annals of Natural History*, vol. xvii.

"In the fruit, as in the calyx, this author believes that horizontal disruption arises from the force of cohesion of the parts of the circle, the absence of any of the causes favourable to dehiscence along the midrib of the carpellary leaf, and the operation of some force pressing either from without or from within on one particular line encircling the fruit. In the circumscissile capsule of Anagallis, he states that the central free receptacle with the seeds upon it continuing to enlarge in both diameters after the envelope has ceased to grow, and having occupied from the first the entire cavity, it is

naturally to be expected, since the chief extension of the interior parts is upwards (the natural direction of growth), while the enlargement of the seeds in the lower half tends to press back the parts of the lower hemisphere, that uniform and regular pressure will resolve a nearly spherical capsule into two equal hemispheres. This remark he applies to Centunculus also, but confesses himself at a loss to give any reason why the opening of Trientalis, which depends on the same general causes, should be irregular. For the separation of the lid of the capsule in Hyoscyamus he accounts by the contraction and rigidity of the throat of the calyx exercising a gradually increasing pressure around the upper part of the capsule, and thus causing its separation by the first of the general principles laid down. Lecythis, he thinks is to be explained by the third of his general principles. In illustration he refers to a monstrosity of the common Tulip. In this monstrosity, the upper leaf, being unusually developed, cohered by its edges so firmly as to imprison the flower, and this constraint occurring at a period when the stalk was increasing in length, and previous to any considerable enlargement of the flower-bud, the force applied was chiefly vertical, and carried off the upper part of the leaf in the form of a calyptra, leaving the lower part in the shape of a cup, from the centre of which the stem appeared to rise. The separation of the lid of the capsule of Lecythis, Mr Hincks believes to be effected in an analogous manner; the septa which form the two or four cells into which the fruit is divided, meet in a thickened axis, and the outer part of the fruit becoming (partly from its natural texture, and partly from the adherence of the torus and calyx) hard, solid, and fully grown, while the axis continues slowly to extend, and thus to press upwards that portion of the capsule which rests upon it, causes that portion first to become slightly prominent, and finally by a strain upon the vessels of that particular part to fall off in the shape of a lid. In Couroupita the pressure is sufficient to mark the surface of the fruit with a prominence, but from the partitions giving way early, and from the abundant juices produced in the interior, there has not been sufficient pressure to occasion disruption. In all the species

of Lecythis, the extent of the loose cover corresponds with the extent of the axis, and what remains of the latter continues attached to it. As regards Lomentaceous fruits in general, the author believes that the intervals between the seeds being sufficient to admit of the sides of the fruit cohering (which is promoted in particular instances by special causes), the swelling of the seeds afterwards stretches the parts over them in a degree which this coherence prevents from being equally distributed, drags the tissue forcibly from the junctures which are fixed points, and thus there being a strain in each direction from the middle line of the juncture the contraction of drying in the ripening of the fruit effects the separation."

Valvular dehiscence, which is by far the most common mode by which pericarps open, must not be confounded with either *rupturing* or *solubility*,—irregular and unusual contrivances of nature for facilitating the dispersion of seeds. In valvular dehiscence the openings have a certain reference to the cells, as has been already shown; but neither rupturing nor solubility bear any distinct relation to the cells. *Rupturing* consists in a spontaneous contraction of a portion of the pericarp, by which its texture is broken through, and holes formed, as in Antirrhinum and Campanula. *Solubility* arises from the presence of certain transverse contractions of a one-celled pericarp, through which it finally separates into several closed portions, as in Ornithopus.

For the nature of the placenta and umbilical cord see the observations under ovary. Of these parts, which are mere modifications of each other, the former often acquires a spongy dilated substance, occasionally dividing the cells by spurious dissepiments, and often giving to the fruit an appearance much at variance with its true nature.

In some seeds, as Euonymus europæus, it becomes exceedingly dilated around each seed, forming an additional envelope, called *aril*. The true character of this organ was unknown till it was settled by Richard: before his time the term was applied, not only in its true sense to an enlargement of the

placenta, but also to the endocarp of certain Cinchonads and Rueworts, to the seed-coat of Jasminum, of Orchids, and others, and even to the perianth of Carex. A very remarkable instance of the aril is to be found in the nutmeg, in which it forms the part called the *mace* surrounding the seed. It is never developed until after the fertilisation of the ovule. It will be further and much more particularly treated of, when speaking of the *seed*.

Having thus explained the structure of the pericarp, it is in the next place necessary to inquire into the nature of its modifications, which in systematic botany are of considerable importance. It is, on the one hand, very much to be regretted that the terms employed in this department of the science, which is that of Carpology, have been often used so vaguely as to have no exact meaning; while, on the other hand, they have been so exceedingly multiplied by various writers, that the language of carpology is a mere chaos. In practice but a small number of terms is actually employed; but for collections of fruits, or minute carpological arrangements, a large number is desirable; and it cannot be doubted that, if it were not for the excessive inconvenience of overburdening the science with words, it would conduce to clearness of description if botanists would agree to make use of some precise and uniform nomenclature.

What, for instance, can be more embarrassing than to find the term *nut* applied to the superior plurilocular pericarp of Verbena, the gland of Corylus, and the achenia of Rosa and Borago: and that of *berry* to the fleshy envelope of Taxus, the polyspermous inferior fruit of Ribes, the succulent calyx of Blitum, and several other things?

So much discordance, indeed, exists in the application of terms expressive of the modifications of fruit, that it is quite indispensable to give the definitions of some of the most eminent writers upon the subject in their own words, in order that the meaning attached by those authors to carpological terms, when employed by themselves, may be clearly understood.

In the phraseology of *writers antecedent to Linnæus*, the

following are the only terms of this description employed; viz.:—

1. *Bacca,* a berry: any fleshy fruit.
2. *Acinus,* a bunch of fleshy fruit: especially a bunch of grapes.
3. *Cachrys,* a cone: as of the pine tree.
4. *Pilula,* a cone like the Galbulus of modern botanists.
5. *Folliculus* (Fuchs), any kind of capsule.
6. *Grossus,* the fruit of the fig unripe.
7. *Siliqua,* the coating of any fruit.

In his *Philosophia Botanica,* LINNÆUS gives the following definitions of the terms he employs:—

1. *Capsula,* hollow, and dehiscing in a determinate manner.
2. *Siliqua,* two-valved, with the seeds attached to both sutures.
3. *Legumen,* two-valved, with the seeds attached to one suture only.
4. *Conceptaculum,* one-valved, opening longitudinally on one side, and distinct from the seeds.
5. *Drupa,* fleshy, without valves, containing a nut.
6. *Pomum,* fleshy, without valves, containing a capsule.
7. *Bacca,* fleshy, without valves, containing naked seeds.
8. *Strobilus,* an amentum converted into a pericarp.

GÆRTNER has the following, with definitions annexed to them:—

1. *Capsula,* a dry, membranous, coriaceous, or woody pericarp, sometimes valveless, but more commonly dehiscing with valves. Its varieties are,—
   a. *Utriculus,* a unilocular one-seeded capsule, very thin and transparent, and constantly valvular; as in Chenopodium, Atriplex, Adonis.
   b. *Samara,* an indehiscent, winged, one- or two-celled capsule; as Ulmus, Acer, Liriodendron.
   c. *Folliculus,* a double one-celled, one-valved, membranous, coriaceous capsule, dehiscing on the inside, and either bearing the seed on each margin of its suture, or on a receptacle common to both margins; as Asclepias, Cinchona, and Vinca.
2. *Nux,* a hard pericarp, either indehiscent or never dividing into more than two valves; as in Nelumbium, Boragineæ, and Anacardium.

3. *Coccum,* a pericarp of dry elastic pieces or *coccules,* as in Diosma, Dictamnus, Euphorbia.
4. *Drupa,* an indehiscent pericarp with a variable rind, very different in substance from the *putamen,* which is bony, as in Lantana, Cocos, Sparganium, Gaura, &c.
5. *Bacca,* any soft pericarp, whether succulent or otherwise; provided it does not dehisce into regular valves, nor contain a single stone adhering to it. Of this the following are kinds:—
   a. *Acinus,* a soft, succulent, semi-transparent, unilocular berry, with one or two hard seeds; as the Grape, Rivina, Rhipsalis, Rubus, Grossularia, &c.
   b. *Pomum,* a succulent or fleshy, two- or many-celled berry, the dissepiments of which are fleshy or bony, and coherent at the axis; as Pyrus, Cratægus, Cydonia, Sapota, and others.
   c. *Pepo,* a fleshy berry, with the seeds attached at a distance from the axis, upon the parietes of the pericarp; as Cucumis, Stratiotes, Passiflora, Vareca, and others.

To the term *bacca,* all other succulent fruits are referred which do not belong to Acinus, Pomum, or Pepo; as Garcinia, Caryophyllus, Cucubalus, Hedera.

6. *Legumen,* the fruit of Leguminosæ.
7. *Siliqua* and *Silicula,* the fruit of Cruciferæ.

WILLDENOW defines those employed by him in the following manner:—

1. *Utriculus,* a thin skin enclosing a single seed. Adonis, Galium, Amaranthus.
2. *Samara,* a pericarp containing one seed, or at most two, and surrounded by a thin membrane, either along its whole circumference, or at the point, or even at the side. Ulmus, Acer, Betula.
3. *Folliculus,* an oblong pericarp bursting longitudinally on one side, and filled with seeds. Vinca.
4. *Capsula,* a pericarp consisting of a thin coat containing many seeds, often divided into cells, and assuming various forms. Silene, Primula, Scrophularia, Euphorbia, Magnolia.

5. *Nux*, a seed covered with a hard shell which does not burst. Corylus, Quercus, Cannabis.
6. *Drupa*, a nut covered with a thick succulent or cartilaginous coat. Prunus, Cocos, Tetragonia, Juglans, Myristica, Sparganium.
7. *Bacca*, a succulent fruit containing several seeds, and not dehiscing. It encloses the seeds without any determinate order, or it is divided by a thin membrane into cells. Ribes, Garcinia, Hedera, Tilia. Rubus has a compound bacca.
8. *Pomum*, a fleshy fruit that internally contains a capsule for the seed. It differs from the celled berry in having a perfect capsule in the heart. Pyrus.
9. *Pepo*, a succulent fruit which has its seeds attached to the inner surface of the rind. Cucumis, Passiflora, Stratiotes.
10. *Siliqua*, a dry elongated pericarp consisting of two valves held together by a common permanent suture. Cruciferæ. *Silicula* is a small form of the same.
11. *Legumen*, a dry elongated pericarp consisting of two valves externally forming two sutures. Leguminosæ.
12. *Lomentum*, a legumen divided internally by spurious dissepiments, not dehiscing longitudinally, but either remaining always closed, as in Cathartocarpus fistula, or separating into pieces at transverse contractions along its length, as in Ornithopus.

The following are enumerated as *spurious fruits* :—

13. *Strobilus*, an amentum the scales of which have become woody. Pinus.
14. *Spurious capsule*. Fagus, Rumex, Carex.
15. *Spurious nut*. Trapa, Coix, Mirabilis.
16. *Spurious drupe*. Taxus, Anacardium, Semecarpus.
17. *Spurious bacca*. Juniperus, Fragaria, Basella.

By this author the names of fruits are, perhaps, more loosely and inaccurately applied than by any other.

Link objects to applying particular names to variations in anatomical structure; observing, "that botanists have strayed far from the right road in distinguishing these terms by characters which are precise and difficult to seize. Terms are

only applied to distinct parts, as the leaf, peduncle, calyx, and stamens, and not to modifications of them. Who has ever thought of giving a distinct name to a labiate or papilionaceous corolla, or who to a pinnated leaf?" But this reasoning loses its value, when it is considered that the fruit is subject to infinitely greater diversity of structure than any other organ, and that names for these modifications are useful, for the sake of avoiding a minute explanation of the complex differences upon which they depend. Besides, to admit, as Link actually does, such names as capsula, &c., is abandoning the argument; and when the following definitions, which this learned botanist has proposed, are considered, I think that little doubt will exist as to whether terms should be employed in the manner recommended by himself, or with the minute accuracy of the French. According to Professor Link, the following are the limits of carpological nomenclature :—

1. *Capsula,* any dry, membranous, or coriaceous, pericarp.
2. *Capsella,* the same, if small and one-seeded.
3. *Nux,* externally hard.
4. *Nucula,* externally hard, small, and one-seeded.
5. *Drupa,* externally soft, internally hard.
6. *Pomum,* fleshy or succulent, and large.
7. *Bacca,* fleshy or succulent, and small.
8. *Bacca sicca,* fleshy when unripe, dry when ripe, and then distinguishable from the capsule by not being brown.
9. *Legumen,*
10. *Siliqua,* } the pericarps of certain natural orders.
11. *Amphispermium,* a pericarpium which is of the same figure as the seed it contains.

In more recent times there have been three principal attempts at classing and naming the different modifications of fruit; namely, those of Richard, Mirbel, and Desvaux. These writers have all distinguished a considerable number of variations, of which it is important to be aware for some purposes, although their nomenclature is not much employed in practice. But, in proportion as the utility of a classification of fruit consists in its theoretical explanation of structure

rather than in a strict applicability to practice, it becomes important that it should be founded upon characters which are connected with internal and physiological distinctions rather than with external and arbitrary forms. Viewing the subject thus, it is not to be concealed, that, notwithstanding the undoubted experience and talent of the writers just mentioned, their carpological systems are essentially defective. Besides this, each of the three writers has felt himself justified in contriving a nomenclature at variance with that of his predecessors, for reasons which it is difficult to comprehend.

If a complete carpological nomenclature is to be established, it ought to be carried farther than has yet been done, and to depend upon principles of a more strictly theoretical character. I have accordingly ventured to propose an arrangement, in which an attempt has been made to adjust the synonymes of carpological writers, and in which the names that seem to be most legitimate are retained in every case, their definitions only being altered; previously to which I shall briefly explain the methods of Richard, Mirbel, and Desvaux.

The Arrangement of Richard.

Class 1. Simple fruits.
- § 1. Dry.
  - * Indehiscent.
  - * * Dehiscent.
- § 2. Fleshy.

Class 2. Multiplied fruits.

Class 3. Aggregate or compound fruits.

The Arrangement of Mirbel.

Class 1. Gymnocarpians. Fruit not disguised by the adherence of any other organ than the calyx.

Ord. 1. *Carcerular*. Pericarpium indehiscent, but sometimes with apparent sutures, generally dry, superior or inferior, mostly unilocular and monospermous, sometimes plurilocular and polyspermous.

Ord. 2. *Capsular.* Pericarpium dry, superior, or inferior, opening by valves, but never separating into distinct pieces or cocci.

Ord. 3. *Dieresilian.* Pericarpium superior or inferior, dry, regular, and monocephalous (that is, having one common style), composed of several distinct pieces arranged systematically round a central real or imaginary axis, and separating at maturity.

Ord. 4. *Etærionar.* Pericarps several, irregular, superior, one- or many-seeded, with a suture at the back.

Ord. 5. *Cenobionar.* A regular fruit divided to the base into several acephalous pericarpia; that is to say, not marked on the summit by the stigmatic scar, the style having been inserted at their base.

Ord. 6. *Drupaceous.* Pericarpium indehiscent, fleshy externally, bony internally.

Ord. 7. *Baccate.* Succulent, many-seeded.

Class 2. Angiocarpians. Fruit seated in envelopes not forming part of the calyx.

The Arrangement of Desvaux.

Class 1. Pericarpium dry.

Ord. 1. Simple fruits.

§ Indehiscent.

§ § Dehiscent.

Ord. 2. Dry compound fruits.

Class 2. Pericarpium fleshy.

Ord. 1. Simple fruits.

Ord. 2. Compound fruits.

In explanation of the principles upon which the classification of fruit which I now venture to propose is founded, it will of course be expected that I should offer some observations. In the first place, I have made it depend primarily upon the structure of the ovary, by which the fruit is of necessity influenced in a greater degree than by anything

else, the fruit itself being only the ovary matured. In using the terms simple and compound, I have employed them precisely in the sense that has been attributed to them in my remarks upon the ovary; being of opinion that, in an arrangement like the following and those which have preceded it, in which theoretical rather than practical purposes are to be served, the principles on which it depends should be conformable to the strictest theoretical rules of structure. A consideration of the fruit, without reference to the ovary, necessarily induces a degree of uncertainty as to the real nature of the fruit; the abortion and obliteration to which almost every part of it is more or less subject, often disguising it to such a degree that the most acute carpologist would be unable to determine its true structure, from an examination of it in a ripe state only. In simple fruits are stationed those forms in which the ovaries are multiplied so as to resemble a compound fruit in every respect except their cohesion, they remaining simple. But, as the passage which is thus formed from simple to compound fruits is deviated from materially when the ovaries are placed in more than a single series, I have found it advisable to constitute a particular class of such, under the name of aggregate fruit. Care must be taken not to confound these with the fourth class containing collective fruits, as has been done by more carpologists than one. While the true aggregate fruit is produced by the ovaries of a single flower, a collective fruit, if aggregate, is produced by the ovaries of many flowers; a most important difference. As the pericarp is necessarily much affected by the calyx when the two adhere so as to form a single body, it is indispensable, if a clear idea is to be attached to the genera of carpology, that inferior and superior fruits should not be confounded under the same name: for this reason I have in all cases founded a distinction upon that character.

In order to facilitate the knowledge of the limits of the genera of carpology, the following analytical table will be found convenient for reference. It is succeeded by the characters of the genera in as much detail as is necessary for the perfect understanding of their application.

CLASS I. Fruit simple. APOCARPI.

One- or two-seeded :

Membranous, ... UTRICULUS.

Dry and bony, ... ACHÆNIUM.

Fleshy externally, bony internally, . . DRUPA.

Many-seeded :

Dehiscent :

One-valved, ... FOLLICULUS.

Two-valved, ... LEGUMEN.

Indehiscent, ... LOMENTUM.

CLASS II. Fruit aggregate. AGGREGATI.

Ovaria elevated above the calyx :

Pericarpia distinct, ... ETÆRIO.

Pericarpia cohering into a solid mass, . . . SYNCARPIUM.

Ovaria enclosed within the fleshy tube of the calyx, . CYNARRHODUM.

CLASS III. Fruit compound. SYNCARPI.

Sect. 1. Superior :

A. Pericarpium dry externally :

Indehiscent :

One-celled, ... CARYOPSIS.

Many-celled :

Dry internally :

Apterous, ... CARCERULUS.

Winged, ... SAMARA.

Pulpy internally, ... AMPHISARCA.

Dehiscent :

By a transverse suture, . . . PYXIDIUM.

By elastic cocci, ... REGMA.

By a longitudinal suture, . . . CONCEPTACULUM.

By valves :

Placentæ opposite the lobes of the stigma :

Linear, ... SILIQUA.

Roundish, . . . SILICULA.

Placentæ alternate with the lobes of the stigma :

Valves separating from the replum, CERATIUM.

Replum none, . . . CAPSULA.

B. Pericarpium fleshy :

Indehiscent :

Sarcocarpium separable, . . . HESPERIDIUM.

Sarcocarpium inseparable, . . . NUCULANIUM.

Dehiscent, ... TRYMA.

Sect. 2. Inferior :

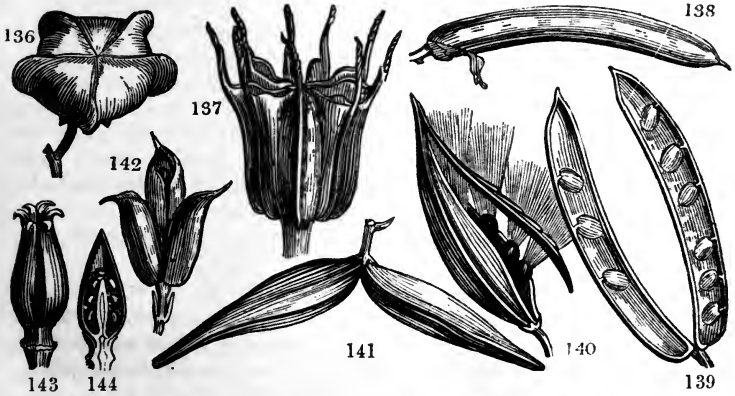
A. Pericarpium dry :

Indehiscent :

Cells two or more, ... CREMOCARPIUM.

Cell one :
Surrounded by a cupulate involucrum, GLANS.
Destitute of a cupula, . . . CYPSELA.
Dehiscent or rupturing, . . . DIPLOTEGIA.
B. Pericarpium fleshy :
Epicarpium hard :
Seeds parietal, ... PEPO.
Seeds not parietal, . . . BALAUSTA.
Epicarpium soft :
Cells obliterated, or unilocular, . . BACCA.
Cells distinct, ... POMUM.

CLASS IV. Collective fruits. ANTHOCARPI.
Single :
Perianthum indurated, dry, ... DICLESIUM.
Perianthum fleshy, ... SPHALEROCARPIUM.
Aggregate :
Hollow, ... SYCONUS.
Convex :
An indurated amentum, . . . STROBILUS.
A succulent spike, ... SOROSIS.



136. Syncarpous Capsule of Euonymus. 137. Apocarpous Capsule of Nigella. 138. Legumen. 139. Legumen with the two valves opened. 140. Folliculus. 141. Conceptaculum, or Double Folliculus. 142. Apocarpous Capsule of Delphinium. 143. Capsule of Lychnis. 144. Capsule of Lychnis cut through, and showing the free central placenta.

CLASS I. Fruit simple. APOCARPI.

Ovaria strictly simple; a single series only produced by a single flower.

I. UTRICULUS, *Gærtner.* (Cystidium, *Link.*)

One-celled, one- or few-seeded, superior, membranous, frequently dehiscent by a transverse incision. This differs from the *pyxidium* in texture, being strictly simple, *i. e.* not proceeding from an ovarium with obliterated dissepiments.

Example. Amaranthus, Chenopodium.

II. ACHÆNIUM. (Akenium, *of many;* Spermidium; Xylodium, *Desv.*; Thecidium, *Mirb.*; Nux, *Linn.*)

One-seeded, one-celled, superior, indehiscent, hard, dry, with the integuments of the seed distinct from it.

Linnæus includes this among his seeds, defining it "semen tectum epidermide osseâ." I have somewhere seen it named Spermidium; a good term if it were wanted. M. Desvaux calls the nut of Anacardium a Xylodium.

Examples. Lithospermum, Borago.

III. DRUPA. *Drupe. fig.* 165.

One-celled, one- or two-seeded, superior, indehiscent, the outer coat (*naucum*) soft and fleshy, and separable from the inner or *endocarpium* (the stone), which is hard and bony; proceeding from an ovarium which is perfectly simple. This is the strict definition of the term drupa, which cannot strictly be applied to any compound fruit, as that of Cocos, certain Verbenaceæ, and others, as it often is. Fruits of the last description are generally carcerules with a drupaceous coat. The *stone* of this fruit is the *Nux* of Richard, but not of others.

Examples. Peach, Plum, Apricot.

IV. FOLLICULUS. *Follicle.* (Hemigyrus, *Desvaux;* Plopocarpium, *Desv.*) *fig.* 141.

One-celled, one- or many-seeded, one-valved, superior, dehiscent by a suture along its face, and bearing its seeds at the base, or on each margin of the suture. This differs from the legumen in nothing but its having one valve instead of two. The Hemigyrus of Desvaux is the fruit of Proteaceæ, and differs from the follicle in nothing of importance. When several follicles are in a single flower, as in Nigella and Delphinium, they constitute a form of fruit called Plopocarpium by Desvaux, and admitted into his Etærio by Mirbel.

Examples. Pæonia, Banksia, Nigella.

V. LEGUMEN. *Pod.* (Legumen, *Linn.*; Gousse, *Fr.*) *fig.* 138, 139.

One-celled, one- or many-seeded, two-valved, superior, dehiscent by a suture along both its face and its back, and bearing its seeds on each margin of the ventral suture. This differs from the follicle in nothing except its dehiscing by two valves. In Astragalus two spurious cells are formed by the projection inwards of either the dorsal or ventral suture, which forms a sort of dissepiment; and in Cassia a great number of transverse diaphragms (phragmata) are formed by projections of the placenta. Sometimes the legumen is indehiscent, as in Cathartocarpus, Cassia fistula, and others; but the line of dehiscence is in such species indicated by the presence of sutures. When the two sutures of the legumen separate from the valves, they form a kind of frame called *replum*, as in Carmichaelia.

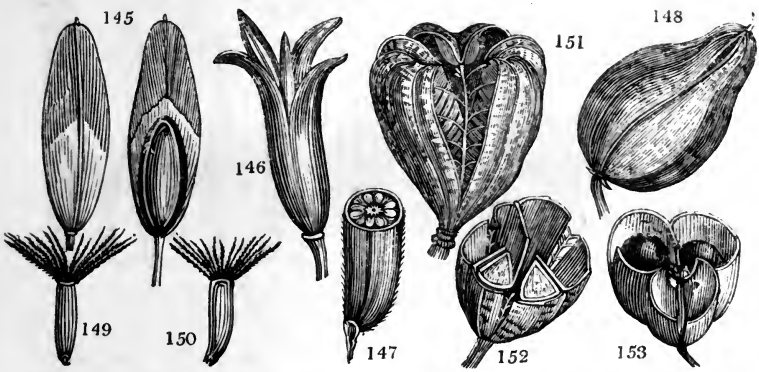
Examples. Bean, Pea, Clover.

VI. LOMENTUM. (Legumen lomentaceum, *Rich.*)

Differs from the legumen in being contracted in the spaces between such seed, and there separating into distinct pieces; or indehiscent, but divided by

internal spurious dissepiments, whence it appears at maturity to consist of many articulations and divisions.

Example. Ornithopus.



145. Samara. 146. Capsule of Rhododendron. 147. Capsule of Rhododendron divided across. 148. Capsule of Staphylea. 149, 150. Cypsela of Compositæ. 151. Capsule of Aristolochia. 152. Capsule of Aristolochia cut across. 153. Capsule of Staphylea cut across.

Class II. Fruit aggregate. AGGREGATI.

Ovaria strictly simple; more than a single series produced by each flower.

VII. Etærio, *Mirb.* ("Polychorion, *Mirb*;" Polysecus, *Desvaux;* Amalthea, *Desv.*; Erythrostomum, *Desvaux.*) *fig.* 163.

Ovaries distinct; pericarpia indehiscent, either dry upon a dry receptacle, as Ranunculus, dry upon a fleshy receptacle, as Strawberry, or fleshy upon a dry receptacle, as Rubus. The last is very near the syncarpium, from which it differs in the ovaria not coalescing into a single mass. It is Desvaux's Erythrostomum. This term is applied less strictly by M. Mirbel, who admits into it dehiscent pericarpia, not placed upon an elevated receptacle, as Delphinium and Pæonia; but the fruit of these plants is better understood to be a union of several follicules within a single flower. If there is no elevated receptacle, we have Desvaux's Amalthea. The parts of an Etærio are Achenia.

Examples. Ranunculus, Fragaria, Rubus.

VIII. Syncarpium. (Syncarpium, *Rich.*; Asimina, *Desv.*)

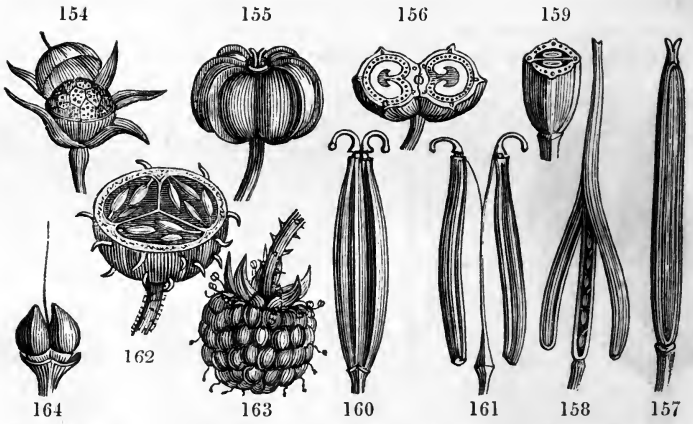
Ovaries cohering into a solid mass, with a slender receptacle.

Examples. Anona, Magnolia.

IX. Cynarrhodum. (Cynarrhodum, *Officin. Desvaux.*)

Ovaries distinct; pericarpia hard, indehiscent, enclosed within the fleshy tube of a calyx.

Examples. Rosa, Calycanthus.



154. Pyxidium of Anagallis. 155. Cremocarpium of Apiaceæ. 156. Cremocarpium of Apiaceæ cut across. 157. Siliqua of Cruciferæ. 158. Siliqua of Cruciferæ with the valves separating. 159. Siliqua of Cruciferæ cut across. 160. Cremocarpium of Apiaceæ. 161. Cremocarpium of Apiaceæ with the halves separating from their axis. 162. Bacca. 163. Etærio of Rubus. 164. Etærio of Boraginaceæ.

CLASS III. Fruit compound. SYNCARPI.

Ovaria compound.

Sect. 1. Fruit superior.

A. Pericarpium dry.

X. CARYOPSIS. (Cariopsis, *Rich.*; Cerio, *Mirb.*)

One-celled, one-seeded, superior, indehiscent, dry, with the integuments of the seed cohering inseparably with the endocarpium, so that the two are undistinguishable; in the ovarium state evincing its compound nature by the presence of two or more stigmata; but nevertheless unilocular, and having but one ovulum.

Examples. Wheat, Barley, Maize.

XI. REGMA, *Mirb.* (Elaterium, *Rich.*; Capsula tricocca, *L.*)

Three or more celled, few-seeded, superior, dry, the cells bursting from the axis with elasticity into two valves. The outer coat is frequently softer than the endocarpium or inner coat, and separates from it when ripe; such regmata are drupaceous. The cells of this kind of fruit are called *cocci*.

Example. Euphorbia.

XII. CARCERULUS, *Mirb.* (Dieresilis, *Mirb.*; Cœnobio, *Mirb.*; Synochorion, *Mirb.*; Sterigmum, *Desvaux*; Microbasis, *Desvaux*; Polexostylus, *Mirb.*; Sarcobasis, *Dec.*, *Desv.*; Baccaularius, *Desv.*)

Many-celled, superior: cells dry, indehiscent, few-seeded, cohering by a common style round a common axis. From this the Dieresilis of Mirbel does not differ in any essential degree. The same writer calls the fruit of Labiatæ (*fig.* 162.), which Linnæus and his followers mistake for naked seeds,

Cœnobio: it differs from the Carcerulus in nothing but the low insertion of the style into the ovaria, and the distinctness of the latter.

Examples. Tilia, Tropæolum, Malva.

XIII. SAMARA, *Gærtn. Key.* (Pteridium, *Mirb.*; Pterodium, *Desv.*) *fig.* 145.

Two or more celled, superior; cells few-seeded, indehiscent, dry; elongated into wing-like expansions. This is nothing but a modification of the Carcerule.

Examples. Fraxinus, Acer, Ulmus.

XIV. PYXIDIUM. (Pyxidium, *Ehr., Rich., Mirb.*; Capsula circumscissa, *L.*) *fig.* 154.

One-celled, many-seeded; superior, or nearly so; dry, often of a thin texture; dehiscent by a transverse incision, so that when ripe the seed and their placenta appear as if seated in a cup, covered with a lid. This fruit is one-celled by the obliteration of the dissepiments of several carpella, as is apparent from the bundles of vessels which pass from the style through the pericarpium down into the receptacle.

Example. Anagallis.

XV. CONCEPTACULUM. (Conceptaculum, *Linn.*; Double Follicule, *Mirb.*) *fig.* 141.

Two-celled, many-seeded, superior, separating into two portions, the seeds of which do not adhere to marginal placentæ, as in the folliculus, to which this closely approaches, but separate from their placentæ, and lie loose in the cavity of each cell.

Examples. Asclepias, Echites.

XVI. SILIQUA, *Linn. fig.* 157, 158, 159.

One- or two-celled, many-seeded, superior, linear, dehiscent by two valves separating from the replum; seeds attached to two placentæ adhering to the replum, and *opposite* to the lobes of the stigma. The dissepiment of this fruit is considered a spurious one formed by the projecting placentæ, which sometimes do not meet in the middle; in which case the dissepiment or phragma has a slit in its centre, and is said to be *fenestrate.*

Examples. Cheiranthus, Arabis.

XVII. SILICULA, *Linn.*

This differs from the latter in nothing but its figure, and in containing fewer seeds. It is never more than four times as long as broad, and often much shorter.

Examples. Thlaspi, Lepidium, Lunaria.

XVIII. CERATIUM. (Capsula siliquiformis, *Dec.*; Conceptaculum, *Desv.*)

One-celled, many-seeded, superior, linear, dehiscent by two valves separating from the replum; seeds attached to two spongy placentæ adhering to the replum, and *alternate* with the lobes of the stigma. Differs from the siliqua in the lobes of the stigma being alternate with the placentæ, not opposite. This, therefore, is regular, while that is irregular, in structure.

Examples. Glaucium, Corydalis, Hypecoum.

XIX. CAPSULA. *Capsule. fig.* 146, 147, 151, 152, 136, 137.

One- or many-celled, many-seeded, superior, dry, dehiscent by valves, always proceeding from a compound ovarium. The valves are variable in their

nature: usually they are at the top of the fruit, and equal in number to the cells; sometimes they are twice the number; occasionally they resemble little pores or holes below the summit, as in the Antirrhinum.

Examples. Digitalis, Primula, Rhododendron.

XX. AMPHISARCA. (Amphisarca, *Desv.*)

Many-celled, many-seeded, superior, indehiscent; indurated or woody externally, pulpy internally.

Examples. Omphalocarpus, Adansonia, Crescentia.

B. Pericarpium fleshy.

XXI. TRYMA. (Tryma, *Watson.*)

Superior, by abortion one-celled, one-seeded, with a two-valved indehiscent endocarpium, and a coriaceous or fleshy valveless sarcocarpium.

Example. Juglans.

XXII. NUCULANIUM. (Nuculanium, *Rich.*; Bacca, *Desvaux.*)

Two or more celled, few- or many-seeded, superior, indehiscent, fleshy, of the same texture throughout, containing more seeds than one, improperly called *nucules* by the younger Richard. This differs scarcely at all from the berry, except in being superior.

Examples. Grape, Achras.

XXIII. HESPERIDIUM. (Hesperidium, *Desv.*, *Rich.*)

Many-celled, few-seeded, superior, indehiscent, covered by a spongy separable rind; the cells easily separable from each other, and containing a mass of pulp, in which the seeds are embedded. The pulp is formed by the cellular tissue, which forms the lining of the cavity of the cells: this cellular tissue is excessively enlarged and succulent, is filled with fluid, and easily coheres into a single mass. The external rind is by M. De Candolle supposed to be an elevated discus of a peculiar kind, analogous to that within which the fruit of Nelumbium is seated; and perhaps its separate texture and slight connexion with the cells of the fruit seem to favour this supposition. But it is difficult to reconcile with such a hypothesis the continuity of the rind with the style and stigma, which is a sure indication of the identity of their origin; and it is certain that the shell of the ovarium and the pericarpium are the same. The most correct explanation of this structure is to consider the rind a union of the epicarp and sarcocarp, analogous to that of the drupa.

Example. Orange.

Sect. 2. Fruit inferior.

A. Pericarpium dry.

XXIV. GLANS. (Glans, *Linn.*, *Desv.*; Calybio, *Mirb.*; Nucula, *Desvaux.*) *fig.* 166.

One-celled, one- or few-seeded, inferior, indehiscent, hard, dry; proceeding from an ovarium containing several cells and several seeds, all of which are abortive but one or two; seated in that kind of persistent involucre called a cupule. The pericarpium is always crowned with the remains of the teeth of the calyx; but they are exceedingly minute, and are easily overlooked.

Sometimes the gland is solitary, and quite naked above, as in the common oak; sometimes there is more than one completely enclosed in the cupule, as the beech and sweet chesnut.

Examples. Quercus, Corylus, Castanea.

XXV. CYPSELA. (Akena, *Necker;* Akenium, *Rich.*; Cypsela, *Mirb.*; Stephanoum, *Desv.*) *fig.* 149, 150.

One-seeded, one-celled, indehiscent, with the integuments of the seed not cohering with the endocarpium; in the ovarium state evincing its compound nature by the presence of two or more stigmata; but nevertheless unilocular and having but one ovulum. Such is the true structure of the Achenium; but as that term is often applied to the simple superior fruits, called Nux by Linnæus, I have thought it better, in order to avoid confusion, to adopt the name Cypsela.

Examples. All Composites.

XXVI. CREMOCARPIUM. (Cremocarpium, *Mirb.*; Polakenium, or Pentakenium, *Rich.*; Carpadelium, *Desv.*) *fig.* 155, 160, 161.

Two- to five-celled, inferior; cells one-seeded, indehiscent, dry, perfectly close at all times; when ripe separating from a common axis. M. Mirbel confines the application of cremocarpium to Umbelliferæ: but it is better to let it apply to all fruits which will come within the above definition. It will then be the same as Richard's Polakenium, excluding those forms in which the fruit is superior. The latter botanist qualifies his term Polakenium according to the number of cells of the fruit: thus when there are two cells it is *diakenium*, three *triakenium*, and so on. M. De Candolle calls the half of the fruit of Umbelliferæ *mericarp*.

Examples. Umbellifers, Aralia, Galium.

XXVII. DIPLOTEGIA. (Diplotegia, *Desv.*)

One- or many-celled, many-seeded, inferior, dry, usually bursting either by pores or valves. This differs from the capsule only in being adherent to the calyx.

Examples. Campanula, Leptospermum.

B. Pericarpium fleshy.

XXVIII. POMUM. *Apple*, or *Pome*. (Melonidium, *Rich.*; Pyridium, *Mirb.*; Pyrenarium, *Desvaux;* Antrum, *Mœnch.*) *fig.* 167.

Two or more celled, few-seeded, inferior, indehiscent, fleshy; the seeds distinctly enclosed in dry cells, with a bony or cartilaginous lining, formed by the cohesion of several ovaria with the sides of the fleshy tube of a calyx, and sometimes with each other. These ovaria are called Parietal by M. Richard. Some forms of Nuculanium and this differ only in the former being distinct from the calyx.

Examples. Apple, Cotoneaster, Cratægus.

XXIX. PEPO. (Peponida, *Rich.*)

One-celled, many-seeded, inferior, indehiscent, fleshy; the seeds attached to parietal pulpy placentæ. This fruit has its cavity frequently filled at maturity

with pulp, in which the seeds are embedded; their point of attachment is, however, never lost. The cavity is also occasionally divided by folds of the placenta into spurious cells, which has given rise to the belief that in Pepo macrocarpus there is a central cell, which is not only untrue but impossible.

Examples. Cucumber, Melon, Gourd.

XXX. BACCA. *Berry.* (Bacca, *L.*; Acrosarcum, *Desvaux.*) *fig.* 162.

One or more celled, many-seeded, inferior, indehiscent, pulpy; the attachment of the seeds lost at maturity, when they become scattered in the substance of the pulp. This is the true meaning of the term berry; which is, however, often otherwise applied, either from mistaking nucules for seeds, or from a misapprehension of the strict limits of the term.

Example. Ribes.

XXXI. BALAUSTA. (Balausta, *Officin. Rich.*)

Many-celled, many-seeded, inferior, indehiscent; the seeds with a pulpy coat, and attached distinctly to their placentæ. The rind was called Malicorium by Ruellius.

Example. Pomegranate.

CLASS IV. Collective Fruits. ANTHOCARPI.

Fruit of which the principal characters are derived from the thickened floral envelopes.

XXXII. DICLESIUM. (Dyclesium, *Desvaux;* Scleranthum, *Mœnch;* Cataclesium, *Desvaux;* Sacellus, *Mirb.*)

Pericarpium indehiscent, one-seeded, enclosed within an indurated perianthium.

Examples. Mirabilis, Spinacia, Salsola.

XXXIII. SPHALEROCARPUM. (Sphalerocarpum, *Desvaux;* Nux baccata *of authors.*)

Pericarpium indehiscent, one-seeded, enclosed within a fleshy perianthium.

Examples. Hippophäe, Taxus, Blitum, Basella.

XXXIV. SYCONUS. (Syconus, *Mirb.*)

A fleshy rachis, having the form of a flattened disk, or of a hollow receptacle, with distinct flowers and dry pericarpia.

Examples. Ficus, Dorstenia, Ambora.

XXXV. STROBILUS. *Cone.* (Conus, or Strobilus, *Rich., Mirb.*; Galbulus, *Gærtn.*; Arcesthide, *Desvaux;* Cachrys, *Fuchs;* Pilula, *Pliny.*) *fig.* 168.

An amentum, the carpella of which are scale-like, spread open, and bear naked seeds; sometimes the scales are thin, with little cohesion; but they often are woody, and cohere into a single tuberculated mass.

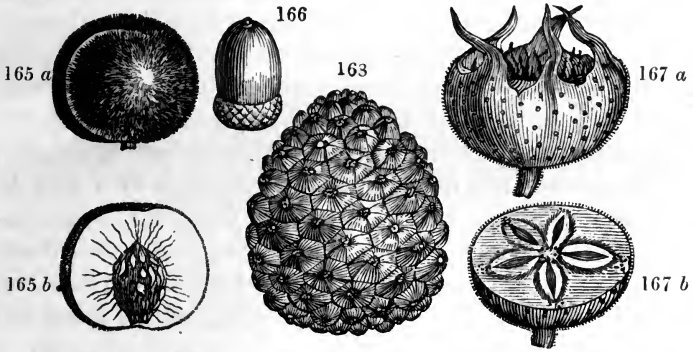
The Galbulus differs from the strobilus only in being round, and having the heads of the carpella much enlarged. The fruit of the Juniper is a Galbulus with fleshy coalescent carpella. Desvaux calls it Arcesthide.

Example. Pinus.

XXXVI. Sorosis. (Sorosis, *Mirb.*)

A spike or raceme converted into a fleshy fruit by the cohesion, in a single mass, of the ovaria and floral envelopes.

Examples. Ananassa, Morus, Artocarpus.



165. *a*, Drupa; *b*, vertical section. 166. Glans. 167. *a*, Pomum; *b*, horizontal section. 168. Strobilus.

15. Of the Seed.

The seed is a body enclosed in a pericarp, is clothed with its own integuments, and contains the rudiment of a future plant. It is the point of development at which vegetation stops, and beyond which no increase, in the same direction with itself, can take place. In a young state it has already been spoken of under the name of ovule; to which I also refer for all that relates to the insertion of seeds.

That side of a seed which is most nearly parallel with the axis of a compound fruit, or the ventral suture or sutural line of a simple fruit, is called the *face*, and the opposite side the *back*. In a compound fruit with parietal placentæ, the placenta is to be considered as the axis with respect to the seed; and that part of the seed which is most nearly parallel with the placenta, as the face. Where the raphe is visible, the face is indicated by that.

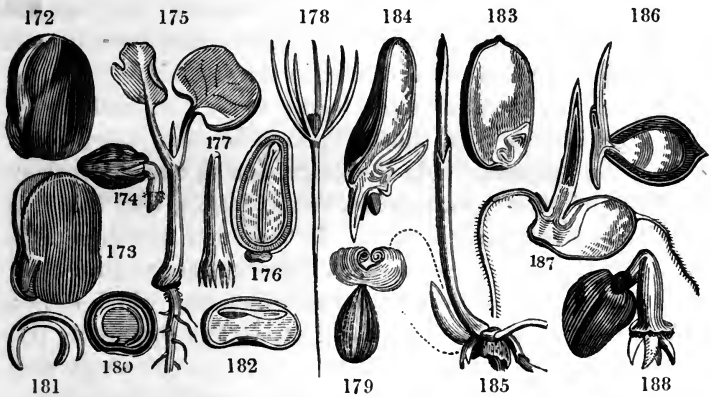
When a seed is flattened lengthwise it is said to be *compressed*, when vertically it is *depressed*; a difference which it is of importance to bear in mind, although it is not always easy to ascertain it: for this purpose it is indispensable that the true base and apex of the seed should be clearly

understood. The base of a seed is always that point by which it is attached to the placenta, and which receives the name of *hilum;* the base being found, it would seem easy to determine the apex, as a line raised perpendicularly upon the hilum, cutting the axis of the seed, ought to indicate the apex at the point where the line passes through the seed-coat; but the apex so indicated would be the geometrical, not the natural apex: for discovering which with precision in seeds, the natural and geometrical apex of which do not correspond, another plan must be followed. If the skin of a seed be carefully examined, it will usually be found that it is composed in great part of lines representing rows of cellular tissue, radiating from some one point towards the base, or, in other words, of lines running upwards from the hilum and meeting in some common point. This point of union or radiation is the true apex, which is not only often far removed from the geometrical apex, but is sometimes even in juxtaposition with the hilum, as in mignionette: in proportion, therefore, to the obliquity of the apex of the seed will be the curve of its axis, which is represented by a line passing through the whole mass of the seed from the base to the apex, accurately following its curve. If the lines above referred to are not easily distinguished, another indication of the apex sometimes resides in a little brown spot or areola, hereafter to be mentioned under the name of *chalaza.*

The integuments of a seed are called the *testa;* the rudiment of a future plant the *embryo* (Plate VI. fig. 1. *b,* &c.); and a substance interposed between the embryo and the testa, the *albumen* (fig. 1. *a,* 5. *a,* &c.)

The *testa,* called also *lorica* by Mirbel, *perisperm* and *episperm* by Richard, and *spermoderm* by De Candolle, consists, according to some, like the pericarp, of three portions; viz., 1. the external integument, *tunica externa* of Willdenow, *testa* of De Candolle; 2. the internal integument, *tunica interna* of Willdenow, *endopleura* of De Candolle, *hilofère* and *tegmen* of Mirbel; and 3., of an intervening substance answering to the sarcocarp, and called *sarcoderm* by De Candolle: this last is chiefly present in seeds with a succulent

testa, and by many is considered a portion of the outer integument, which is the most accurate mode of understanding it.



172. Seed of a Garden Bean. 173. The same, after germination has just begun, and the testa is thrown off. 174. Fruit of Mirabilis Jalapa, with the embryo commencing the act of germination by protruding the radicle. 175. The same, disentangled from the pericarp, and become a young plant. 176. A section of the seed of Sterculia, with the embryo inverted in the midst of albumen. 177. The embryo of Pinus, taken out of the seed, to show its numerous cotyledons. 178. The same, after germination has advanced a little. 179. Seed of Oxalis, with the revolute elastic epidermis of the testa. 180. Seed of Salsola radiata divided vertically, and showing the annular dicotyledonous embryo, rolled round the albumen. 181. Embryo of the same, taken out of the seed. 182. Section of the seed of Cyclamen, showing the transverse embryo lying in the midst of albumen. 183. Section of the fruit of a Grass, with the lateral embryo at the base. 184. The same, with germination just beginning. 185. The same, after germination is completed, and the monocotyledonous embryo become a young plant. 186. Section of seed of Scirpus, with germination begun; the solitary cotyledon is retained within the testa, the plumule and radicle are growing beyond it. 187. Section of a Grass seed germinating; the plumula is directed upwards like a slender horn; the cotyledon is at its base, adhering to the albumen. 188. Seed of Commelina germinating; the cauliculus is protruded, is emitting radicles from its end, and has pushed aside the lid called embryotega.

According to Schleiden, the integuments of the seed experience many changes during the period of ripening, so that their original number can rarely be recognised. They are sometimes all consolidated so as to form but one; or they are broken up into many layers, having no relation to the original number of integuments. In Menyanthes, which has but one integument of the ovule, the seed appears to have two, because of the separation and lignification of the epidermis of that integument; and in Canna there are five layers of tissue resembling integuments, although the ovule has not even one complete integument. In the case of Spurgeworts, Rock Roses (Cistaceæ) and Daphnads, a peculiar process takes place;

namely, upon the seed becoming ripe the external integument is gradually absorbed, until nothing but a thin membrane is left, usually described as *epidermis testæ*, or in the Spurgeworts (Euphorbiaceæ) it has been given as aril; and, on the other hand, the actual modified epidermis testæ has also been described as the aril, for instance, in the Oxalids.

The cellular tissue of the integuments of the seed is very often reticulated. In most Bignoniads, and many other plants, the epidermis is in this state, and in Casuarina there is a layer of spiral vessels below the epidermis, very thin and delicate, and extremely minute. In Swietenia febrifuga there is, below the epidermis, a thick layer of large spiral cells, which have little cohesion with each other, and which form a multitude of rather large fusiform sacs lying confusedly (?); this is the most complete case of spiral cells in seeds with which I am acquainted, and it is accompanied by the presence of a bundle of numerous slender spiral vessels in the raphe.

The *outer integument* is either membranous, coriaceous, crustaceous, bony, spongy, fleshy, or woody; its surface is either smooth, polished, rough, or winged, and sometimes is furnished with hairs, as in the cotton and other plants, which, when long, and collected about either extremity, form what is called the *coma* (sometimes also, but improperly, the pappus). It consists of cellular tissue disposed in rows, with or without bundles of vessels intermixed: in colour it is usually of a brown or similar hue: it is readily separated from the inner integument. In Maurandya Barclayana it is formed of reticulated cellular tissue; in Collomia linearis, some Salvias and others, it is caused by elastic spirally twisted fibres enveloped in mucus, and springing outwards when the mucus is dissolved. In the genus Crinum it is of a very fleshy succulent character, and has been mistaken for albumen, from which it is readily known by its vascularity. According to Brown, a peculiarly anomalous kind of partition, which is found lying loose within the fruit of Banksia and Dryandra, without any adhesion either to the pericarp or the seed, is a state of the outer integument; it is said that in those genera the inner membrane (secundine) of the ovule is, before fertilisation, entirely exposed, the primine being reduced

to half, and open its whole length; and that the outer membranes (primines) of the two collateral ovules, although originally distinct, finally contract an adhesion by their corresponding surfaces, and together constitute the anomalous dissepiment. But it may be reasonably doubted whether the integument here called secundine is not primine, and the supposed primine arillus. In Sir Thomas Mitchell's curious Bottle Tree, (Delabechea) the primine is brittle like an egg-shell, and separates spontaneously from the bony secundine, which eventually cracks the apex of the primine and falls through the hole thus formed. The primines, which are held together by entangled hairs, remain in the follicle long after the secundines and their contents have dropped out.

The *inner membrane* (secundine) of the ovule, however, in general appears to be of greater importance as connected with fecundation, than as affording protection to the nucleus at a more advanced period. For in many cases, before impregnation, its perforated apex projects beyond the aperture of the testa, and in some plants puts on the appearance of an obtuse, or even dilated, stigma; while in the ripe seed it is often either entirely obliterated, or exists only as a thin film, which might readily be mistaken for the epidermis of a third membrane, then frequently observable. The apex of the original papilla, which developes itself as nucleus, varies exceedingly in its size in proportion to the entire ovule, if examined in the different families. It often forms a long and nearly cylindrical body, as in Loasa and Pedicularis; in many cases it is shorter, so that that portion of the ovule in which no distinction has taken place between nucleus and integument (the whole being like a fleshy distended stalk) is by far the more predominant, as in all Composites, Canna, Phlox, Polemonium.

"The *third coat* (tercine) is formed by the proper membrane or skin of the nucleus, from whose substance in the unimpregnated ovule it is never, I believe, separable, and at that period is very rarely visible. In the ripe seed it is distinguishable from the inner membrane only by its apex, which is never perforated, is generally acute and more deeply coloured, or even sphacelated."

Mirbel has, however, justly remarked that the primine and the secundine are, in the seed, very frequently confounded; and that, therefore, the word testa is better employed, as one which expresses the outer integument of the seed without reference to its exact origin, which is practically of little importance. The tercine is also, no doubt, often absent. He observes that these mixed integuments often give rise to new kinds of tissue; that in Phaseolus vulgaris the testa consists, indeed, of three distinct layers, but of those the *innermost* was the primine; and that the others, which represent nothing that pre-existed in the ovule, have a horny consistence, and are formed of cylindrical cellules, which elongate outwards, in the direction from the centre to the circumference. And this is probably the structure of the testa of many Leguminous plants.

De Candolle states, that it sometimes happens that the endopleura thickens so much as to have the appearance of albumen, as in Cathartocarpus fistula, and that in such a case, it is only to be distinguished from albumen by gradual observation from the ovule to the ripe seed. This is, however, denied by Schleiden.

One of the innermost integuments is occasionally present in the form of a fleshy sac, interposed between the albumen and the embryo, and enveloping the latter. It is what was called the *vitellus* by Gærtner, and what Richard, by a singular prejudice, considered a dilatation of the radicle of the embryo: to his macropodal form of which he referred the embryo of such plants. Instances of this are found in Nymphæa and its allies, and also in Gingerworts, Peppers, and Saururus. Brown, who first ascertained the fact, considers this sac to be always of the same nature and origin, and to be the sac of the *amnios*.

The end by which the seed is attached to the placenta is called the *hilum* or *umbilicus* (Plate VI. fig. 5. *c*, 17. *e*, 11. *c*, &c.); it is frequently of a different colour from the rest of the seed, not uncommonly being black. In plants with small seeds it is minute, and recognised with difficulty; but in some

it is so large as to occupy fully a third part of the whole surface of the seed, as in the Horsechesnut, Sapotads, and others. Seeds of this kind have been called *nauca*, by Gærtner. In grasses, the hilum is indicated by a brownish spot situated on the face of the seed, and is called by Richard *spilus*. The centre of the hilum, through which the nourishing vessels pass, is called by Turpin the *omphalodium*. Sometimes the testa is enlarged in the form of irregular lumps or protuberances about the umbilicus; these are called *strophiolæ* or *carunculæ;* and the umbilicus, round which they are situated, is said to be strophiolate or carunculate. Mirbel has ascertained that in Euphorbia Lathyris the strophiole is the fungous foramen of the primine; and it is probable that such is often the origin of this tubercle: but at present we know little upon the subject.

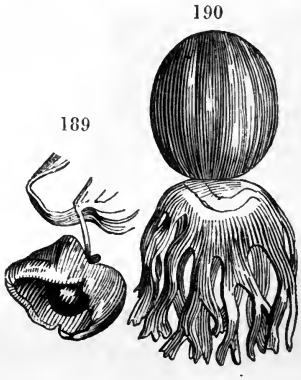
The foramen in the ripe seed constitutes what is called the *micropyle:* it is always opposite the radicle of the embryo; the position of which is, therefore, to be determined without dissection of the seed, by an inspection of the micropyle,—often a practical convenience.

In some seeds, as the Asparagus, Commelina, and others (*fig.* 188.), there is a small callosity at a short distance from the hilum: this callosity gives way like a lid at the time of germination, emitting the radicle, and has been named by Gærtner the *embryotega*.

At the apex of the seed, in the Orange and many other plants, may be perceived upon the testa a small brown spot, formed by the union of certain vessels proceeding from the hilum: this spot is the *chalaza* (Plate VI. fig. 11. *b*). In the orange it is beautifully composed of dense bundles of spiral vessels and spiral ducts, without woody fibre. The vessels which connect the chalaza with the hilum constitute a particular line of communication, called the *raphe:* in most plants this consists of a single line passing up the face of the seed; but in many Citronworts (Aurantiaceæ) and Guttifers it ramifies upon the surface of the testa.

The *raphe* is always a true indication of the face of the seed; and it is very remarkable that the apparent exceptions to this rule only serve to confirm it. Thus, in some species of Euonymus in which the raphe appears to pass along the back, an examination of other species shows that the ovules of such species are in fact resupinate; so that, with them, the line of vascularity representing the raphe is turned away from its true direction by peculiar circumstances. In reality, the chalaza is the place where the secundine and the primine are connected; so that in *orthotropal* seeds, or such as have the apex of the nucleus at the apex of the seed, and in which, consequently, the union of the primine and secundine takes place at the hilum, there can be no apparent chalaza, and consequently no raphe: the two latter can only exist as distinct parts in anatropal or amphitropal seeds, where the base of the nucleus corresponds to the geometrical apex of the seed. Hence, also, there can never be a chalaza without a raphe, nor a raphe without a chalaza.

It is usual to speak of the *aril* of plants (*figs.* 189 and 190.) when speaking of the ovule; but it more properly



comes under consideration along with the ripe seed. As a general rule, it may be stated that everything proceeding from the placenta, and not forming part of the seed, is referable to the aril. Even in plants like Hibbertia volubilis and Euonymus europæus, in which it is of unusual dimensions,

it is scarcely visible in the unimpregnated ovary; and it is stated by Brown, that he is not acquainted with any case in which it covers the foramen of the testa before impregnation. The term aril has been misapplied in many cases to the testa, as in Orchids; and even to a pair of opposite confluent bracts, as in Carex: of these errors, the former arose from imperfect observation, the latter from ignorance of the fundamental principles of Organography.

The true nature of the aril has been carefully and skilfully investigated by M. Planchon, whose memoir throws so much light upon general structure, that I reproduce it with very little abridgment, although at great length.

A. *Difference between True and False Arils.*—We will first examine an aril which possesses all the characters assigned to it by Richard; we will follow its developments, its relations to the ovule and the seed, and we shall be then able to distinguish it from all the organs with which it is at present confounded.

Let us take the genus Passiflora. On cutting the ovary of a young flowerbud of P. triloba, we find numerous conical tumours, which are rudimentary ovules, arranged on three parietal placentæ. In a bud a little more advanced the tumours are longer, their upper part is slightly hooked, and a little below their point two circular rings, close to each other, are found in relief. In these two rings the two integuments of the ovule, as yet scarcely developed, can be distinguished; the point of each tumour is a small nucleus, the base of which is scarcely covered by its integuments, and the hooked curvature of each of them is a commencement of anatropy. A little later, just before expansion, the anatropy is complete; each ovule is become ovoid; the two rings are extended into integuments which are still open at the top; the inner one (*secundine*, Mirb.) projecting beyond the outer (*primine*, Mirb.), and the nucleus projecting through the opening of the inner, which, however, conceals its (the nucleus) base. In the ovary of an expanded flower, the top* of the ovule is

* In this essay, by the top of the ovule is meant the place where the micropyle is found, and where the point of the nucleus ends; hence it is clear that in anatropal and campylotropal ovules, the top will be very near the base if we take the latter to mean not the chalaza, but the hilum.

elongated and curved down on the point of attachment so as to rest on the umbilical cord a little above the hilum; neither the opening of the internal integument nor the point of the nucleus are to be any longer seen; the external integument has covered both, in consequence of its rapid growth. At the same time, however, a very remarkable development has begun on the umbilical cord. At the narrow end of this organ, around the point at which it joins the ovule, we find a circular rim which on one side surrounds obliquely the base of the raphe, and on the other is interposed between the umbilical cord and the ovule. The edges of this ring soon extend and form a sort of membranous sleeve, the free edge of which expands around the hilum. The evolution of the ovules of Passiflora triloba stops here, and I have not been able to follow the subsequent developments because its ovaries are constantly abortive in the hot-houses at Montpellier. Other allied species will, however, suffice. After fecundation each ovule grows rapidly; the membranous sleeve expands more and more, and that part of its edge between the umbilical cord and the ovule extends towards the exostome, and covers the top of the young seed as with a hood. The latter becomes longer by degrees, and at last the ovule, now a seed, is completely concealed in a loose fleshy sac, attached to the border of the hilum and having a large opening next the chalaza. In short, the annular rim, the membranous sleeve, the hood which covers the top of the ovule, and the open sac at its end, which completely conceals the seed, are all one and the same organ in different stages of development.

From the above it appears that this organ is formed after fecundation; that it is an expansion of the umbilical cord; that it does not adhere to the seed except at the hilum; and lastly, that it is completely open at the point opposite its insertion: in this case I do not hesitate, in accordance with the usual terminology, to call the organ a *true aril.*

If all these characters united do not in this case leave any doubt as to the nature of this envelope, it is not so much owing to their real value as to our having followed them in all the stages of the development of the ovule. These characters become doubtful and insufficient when we apply

them to the study of a ripe seed, as is proved by the following remarkable instance.

Nothing is more like the aril of Passionflowers than the so-called envelope found on the seeds of Euonymus; it is a succulent, loose, folded sac covering the seed in a greater or less degree, which does not adhere to it except round the hilum and at the origin of the raphe; the sac is, in short, more or less open next the chalaza. Let us add that this envelope is not formed until after fecundation, and we shall have an apparent identity between this organ and the aril of Passionflowers. We shall, however, see that this identity is apparent only.

Let us take Euonymus latifolius; in its ovary we find two globular ovules suspended parallel to one another at the inner angle of each cell a little below its top. About the time of expansion they become completely anatropal; their outer integument covers the inner one and the nucleus; the raphe, which is prominent, occupies in each of them the side opposite the periphery of the ovary, and the micropyle, on the contrary, is between the point of attachment and the interior angle of the cell at the top of the ovule.

The umbilical cord is white, as the ovule also is next the hilum, but at its other end it is of a rosy colour which gradually extends over the whole seed. For some time after the fall of the petals and stamens the ovule grows, but does not undergo any external change. The edge of the exostome, however, soon thickens, and looks like a rim round its narrow opening, reminding one by its origin, its nature, and even a little by its form of the caruncula of Spurgeworts. This rim, however, grows, expands into a membrane at its edge, and, turning back next the base of the ovule, becomes a hemispherical cap which partly covers the latter, leaving however, at its origin, the micropyle uncovered. This expansion, lastly, increases its surface, draws its opening nearer and nearer the chalaza, and forms around the seed the succulent bag hitherto described as an aril.

When I stated that this sac proceeded solely from the exostome, I have, perhaps, sacrificed exactness to clearness. As the hilum is very near the micropyle, the arilliform expansion starting from the edges of the latter would find the

funicle an obstacle to its extension, and ought, therefore, to have a break in its uniformity: but it is here, as it happens, that the expansion is thickest, and it even adheres, along part of its length, to the base of the raphe, so that it looks as if at this point it proceeded from the latter part. To explain this, we must admit there is a congenial junction between the expansion and the funicle. I ought, perhaps, to add, in order to clear up doubts, that in Euonymus it is very difficult to see the micropyle, when the ovule is considerably developed, because the false aril is folded round its opening, and so completely hides it: but by carefully pulling away the accessory envelope it is quite clear that it proceeds from the edges of the exostome.*

We have seen, in the Passionflowers, an expansion developing around the hilum and *covering the exostome*, by extending over the whole ovule. The same fact, variously modified, is found in other plants.

In Euonymus, on the contrary, no expansion arises *and covers the exostome*; but the edges of this opening expanding a little, turn back from the top towards the base of the ovule, and, developing in this direction, form around the latter a sac open next the chalaza. We shall find in other species, a similar expansion of the edges of the exostome produce very various excrescences on the ovule, which have generally been confounded with those of the umbilical cord.

I have called the expansion of the umbilical cord in Passionflowers an Aril; but this name will not apply to the envelope which as in Euonymus proceeds from the edges of the exostome. Similar productions are as common as true arils: I shall examine them in detail under the name of *false Arils* or of *Arillodes*.

We may, indeed, say that the greatest number of the parts of a seed as yet considered as arils, will come into the new class. In short, the characters assigned to the true aril have been sufficient to distinguish it from the parts of the pericarp and from the integuments of the seed, whilst they are of no

* L. C. Treviranus perfectly traced the developments of the false aril of Euonymus latifolius from the time that it half covered the seed; and he would certainly have arrived at the truth had he traced the progress of this organ from its commencement.

value in cases like that of Euonymus. From the preceding facts I draw the following conclusions, which will place this subject in a better light.

The true aril, an accessory integument of the ovule, is developed round the hilum as the proper integuments are, and covers or would cover the exostome, if we suppose it extended over the whole of the ovule.

The false aril (*arillode*) of Euonymus, &c., an expansion of the edges of the exostome, is often bent back around this opening, but always leaves it exposed.

We can distinguish, even in the seed, the nature of an arilliform envelope, by the place of the micropyle which represents the exostome of the ovule. If the micropyle is hidden by the envelope, or if it would be hidden, if the envelope were extended further, we have a true aril. But if, on the contrary, the micropyle is not covered by the envelope and cannot be, even if the latter is extended, then we have a false aril like that of Euonymus.

When an aril, true or false, forms around an anatropal seed a bag open at its extremity, it can be easily distinguished from a proper envelope, inasmuch as the latter is covered by the raphe, and its opening, the micropyle, is in a direction opposite to that of the arilliform sac.

If the seed is orthotropal and we find a true aril, the opening of the latter is turned to the same side as the micropyle, *i. e.* towards the apex of the ovule; in this case, of which I know of but one example, (Cytinus hypocystis), the aril is blended with the proper integuments of the seed. If, in an orthotropal seed there were an arillode in the form of a sac, it could not be confounded with either a true aril or with a proper integument, because its opening would be next the base of the seed on the side of the point of attachment.

B. *Of the True Aril.*—True arils, though they resemble each other in all essential points, are yet of extremely various forms and sizes. We see them, even in allied species, take every degree of extension from the annular rim, that hardly surrounds the base of the seed, to the sac that entirely covers it. These different states may be found in Dilleniads.

If we take the anatropal ovule of Hibbertia volubilis, a little before the expansion of the flower, we find around its point of attachment a sort of circular thickening formed by its great umbilical cord. The edge of this thickening, at first at a tolerable distance from the exostome, continually approaches, and in the expanded flower nearly reaches this opening. I have not been able to trace the further evolution of the ovules; but it is certain that the expansion does not proceed much further, since, according to certain authors, the ripe seed of this species has only a very short arillary membrane at its base.

In Tetracera, on the contrary, this organ is developed on the seeds as a membranous, coloured sac, which is inserted in a circle around the hilum, and presents at its top a large opening. The free edge of this orifice is more or less slashed somewhat in the same way as a fimbriated petal. The envelope adheres to the hilum of the seed, when the latter is detached from the placenta, and completely covers the micropyle which is beneath it, by the side of the point of attachment, an essential character of a true aril. In a species of Tetracera from Java, I have seen the aril cover the seed completely: in other species it only partially covered the surface of the seeds.

Other genera of the same natural order, as Candollea, Delima, Davilla, Pleuranda, &c., have, it is said, an aril very like that of Tetracera. In the genera Pachynema and Hemistemma, the aril is stated to be reduced to a cupule that receives the base of the seed only.

The genera Samyda and Casearia, although in their general characters far removed from Dilleniads, have, however, an aril, with a large opening and deeply laciniated border. The seeds of these two genera are semi-anatropal, and only differ from those that are completely anatropal by the position of their point of attachment, which, instead of being quite close to the micropyle, is as far from it as from the chalaza. The raphe, very short in the first, only occupies the half of their length. These seeds are completely hidden by the arillary envelope, which inserted round the hilum, necessarily covers the micropyle, a character sufficient to indicate an aril.

Another very curious fact confirms this idea; of the many ovules found on each placenta, there are very few that arrive at maturity, the rest become early abortive, but, nevertheless, remain at the side of the ripe seeds; and, what is a very remarkable fact, even if they are dried and reduced in size as much as possible, their arils for all that become very large sacs. The latter are only a little smaller and not so much cut as the arils of the perfect seeds. This shows that the aril can grow independently of the ovule, just as in some fruits the pericarp continues to grow after the abortion of all the ovules. This observation, which I have made on a Samyda, has also been made by M. Cambessèdes on the seeds of Casearia grandiflora.

Knowing that the aril exists in the Samyds, we shall not be surprised to find it in an allied order, viz., that of Turnerads, where this organ, although it retains its characters, is much modified in form. In a capsule of Turnera, the parietal placentæ bear numerous anatropal seeds, which are nearly cylindrical, obtuse at the two ends, and slightly bent. An umbilical cord, which is rather slender, is inserted at a short distance from the micropyle, and gives rise, below its point of attachment, to a sort of membranous, transparent tongue, which applied, but not adhering to the ventral side of the seed, extends more or less according to the species, without reaching either the dorsal side or the base of the seed. Some people, deceived no doubt by an apparent resemblance between this tongue and that found on the seeds of Corydalis, have called the former a Strophiole, whereas this name applies to the latter only. The strophiole, indeed, is an excrescence of the integument, and has nothing to do with either the umbilical cord or with the micropyle; and I shall show in the sequel that this is the case with the tongue of Corydalis. That of Turnera, on the contrary, belongs so little to the integument, that, when the seed is detached from the umbilical cord which remains fixed to the placenta, the membranous tongue is often found at the other extremity of the latter, and thus its arillary nature admits of no further doubt. This aril, which covers the seed incompletely, is found throughout the whole of Turnerads, if we can, by analogy, apply what

we have seen in Turnera to what has been described in Piriqueta and Wormskioldia.

We are led by natural affinities from Turnerads to Bixads, some genera of which possess the organ we are examining. In Bixa, for example, the numerous turbinate seeds of which are each attached to a long umbilical cord, we find a narrow discoid expansion, arising from the latter around the hilum, and which evidently represents a partially developed aril. The umbilical cords adhering to the placenta after the seeds have fallen resemble little nails, the heads of which are formed by the arillary expansion; the connexion between these cords and the aril cannot be more clear than in this case.

I have nothing more to add concerning the aril of Bixa; but on the seeds of this genus there is another excrescence that merits our attention. These seeds are anatropal, with a deep furrow extending on their surface from the hilum to the chalaza, and inclosing the raphe. The latter lying in a superficial pulpy layer of the external integument, only becomes visible a little below the point where the vessels that compose it expand into the chalaza on the inner integument. In this small portion of its length that can be seen, it forms on the seed an elevated, hard, shining line, expanded at its end into a circular, lobed, crustaceous, shiny disc, which is only attached to the seed by its centre, like a flattened button with a very short stem.

Some physiologists see in the raphe a portion of the umbilical cord, which, completely free, when the ovule is orthotropal, adheres to the length of the latter, thus making it anatropal; and they, perhaps, would explain the origin of these two discoid expansions, by looking upon them as two arils arising from the umbilical cord at two different periods; the first formed, being developed around the hilum when the ovule was orthotropal, the point of its attachment is confounded with the chalaza; the other, formed at the new point of attachment in the anatropal ovule: this point of attachment is separated from the former and from the chalaza by the whole length of the raphe. These two expansions would be found on the seed, the first near the chalaza, the

second at the hilum, and the raphe between them would be a sort of internode intimately adhering to the integument of the ovule. This point of view I take to be more ingenious than correct; for I cannot conceive that a portion of the umbilical cord at first free, should be afterwards found imbedded in the tissue of the ovulary leaf, under the epidermis, which is perfectly unbroken, and often under several crustaceous layers of the integument. Besides, the raphe is generally a medial nervure which sends out along its entire length, lateral nervures, and which branches at its origin before reaching the chalaza. These facts prove that this part is not more independent of the exterior ovulary leaf than the midrib is of an ordinary leaf; and that it plays the part of a midrib with respect to the integument, and of an axis with respect to the more interior parts of the ovule; but they farther prove that there is a congenial adherence and intimate blending between the axis and the nervure, just as on the bracts of the Lime tree (Tilia) the midrib is joined with the floral peduncle from its commencement.

From the frequent examination of the passage from orthotropy to anatropy in ovules, I am convinced that the umbilical cord is never soldered to the ovulary leaf, and if I rightly understand M. De Mirbel, these observations accord with his. The axis of an orthotropal ovule continues in a straight line that of the umbilical cord; the vessels of the latter cross in a vertical direction the thickness of the exterior, to reach the interior integument. But one side of the ovule developing faster than the other, the interior integument is forced to incline to the funicle on the opposite side; and then the vessels extending from the hilum to the chalaza traverse the exterior integument obliquely, and these two points coincide no longer. The hilum remaining fixed, the part of the ovule between it and the chalaza increases rapidly, separating the one from the other, thus forcing the vessels joining them to lengthen into a raphe, in the thickness itself of the testa. The point of attachment of the ovule, it will be seen, is not changed during this transformation; and we cannot admit the possibility of there being two opposite arils on one seed, since there is never but one hilum, and the aril

always proceeds from this point. We ought, then, to consider in Bixa only that discoid expansion which is around the point of attachment as an aril, while the opposite expansion must be looked upon only as an appendage of the integument.

But to return to my subject, from which I have, perhaps, wandered too far, I find the aril, with all its characters, in the genus Nymphæa. The anatropal ovoid seeds of Nymphæa cærulea are entirely covered with a white membranous envelope, which is inserted round the hilum; and being applied, but not adhering to the entire surface of the testa, has but a small opening next the chalaza. Below this envelope, which is a true arillary sac, we find on the side of the point of attachment a very distinct micropyle; this sac has, therefore, been wrongly described as an epidermis of the proper integument. This error would be dispelled by an examination of the seed; but we find still stronger characters in the development of the ovules of another species of the same genus. If the ovary of Nymphæa alba is opened a little before the expansion of the flower, on no one of its numerous anatropal ovules is any trace of an accessory envelope to be found; their exostome is also quite open to view. A simple rim found on the funicle immediately above the hilum, evidently indicates the origin of the membrane which, in Nymphæa cærulea, entirely conceals the seeds; but at a later period, in the same ovules, the rim is extended into a hemispherical cap, crowning their summit and afterwards covering the entire seed. I have not been able myself to observe this transitory state of the aril of Nymphæa alba; but I depend for the accuracy of my statement on De Mirbel's excellent observations on the ovule; than which I can have no better authority.

We might expect to find some sort of aril on the seeds of Nuphar, which is very nearly allied to Nymphæa; however, there is none; the seeds of Nuphar lutea, for example, have no trace of any accessory membrane, either on their crustaceous integument, or on their micropyle, which is very visible. I need not state that this envelope does not exist on the seeds of Nelumbium.

The amphitropal, lenticular seeds of Chamissoa nodiflora (Nat. Ord. Amaranths) have at their base a shallow

furrow, which renders the seed slightly reniform. A white, circular membrane, evidently arising from the umbilical cord, is found fixed round the point of attachment at the bottom of the furrow; passing beyond the latter the membrane covers the micropyle, but extends a very little on the surface of the testa. Here then again we have a true aril; but we may be surprised to find this envelope in a genus lost, as it were, amongst a crowd of others which have no trace of this organ.

In the anatropal and amphitropal seeds, to which our attention has as yet been directed, the distinction between the aril and proper exterior integument is quite plain. The latter, as I have before said, a true ovulary leaf, traversed by the raphe, with the nervures depending on it, forms a complete envelope, the orifice of which, scarcely visible (micropyle) is more or less near the hilum. The aril, on the other hand, often reduced to the dimensions of a rim or of an unilateral tongue, never has any nervures; even when extending over the seed as a hood or sac, it presents a large opening on the side next the chalaza, opposite the micropyle. The same distinctive characters can be easily applied to campylotropal seeds, in which, instead of a raphe, there generally exists a vascular network in the external integument, and the micropyle is always close to the point of attachment. But these characters, though, when combined, of the utmost importance, have not taken separately the same comparative value between themselves. The position of the micropyle, generally determined by that of the radicle, furnishes a very steady character, when compared with the inverse direction of the opening in the aril. The presence of the raphe or of nervures in the proper integument is far from being so constant, and there exists a great number of seeds which have only one entirely cellular integument, whether it proceeds from the secundine, or from the very thin nucleus. If, in such seeds, we suspected an arillary envelope, the position of the micropyle or of the radicle, or, better still, the observation of their development, would resolve all doubts. But if we found a cellular envelope of doubtful nature, in an orthotropal seed with only one cellular integument, we could not then decide with certainty as to its nature, and we ought to remember

that the proper and accessory envelopes of the seeds, like other parts of a plant, are confounded the one with the other by insensible degrees; this I have observed in the seeds of the very anomalous Cytinus hypocistis.

We have hitherto seen in the aril an expansion of the umbilical cord, which, the ovule being considered a bud, is its external leaf. Depending on the retrograde manner in which the integuments of the ovule form, the aril appears very late on the outside of the other envelopes of the ovule, and is the last appendage sent out by the exhausted axis. This feeble production, inclosing no vessels even in its highest state of development, is found immediately below and on the outside of the primine, the most perfect leaf of the ovule, just as the pieces of the disc, the most rudimentary appendages of the floral axis, are found immediately surrounding the carpels, the most vigorous and perfect organs of the whole flower. But M. Aug. de St. Hilaire, the learned and ingenious author of the idea that an aril was a leaf of the ovule, knew too much of vegetable organography not to see that this part, compared in a series of species, insensibly lost its characters of an appendage, and at last became confounded with the simple layer often found at the summit of the umbilical cord; just as the pieces of the disc, which are seldom petaloid, and are more generally represented by little scales, are in many cases nothing but simple projections of the receptacle, which at last disappear altogether. I shall show that the aril passes in allied plants through this series of gradual alterations, and I shall trace it from its usual state until it will be impossible to mark the limit between it and the thickened extremity of the umbilical cord.

On the seeds of many Soapworts (Sapindaceæ) we find the organ in question; whilst on others no trace of it is discoverable. In an undetermined species of Cupania, for example, the great short funicle supporting each seed expands around the hilum into a circular membranous edge, which is a true cup-shaped aril leaving but a small portion of the testa uncovered. The seeds of Paullinia and Schmidelia are only half covered by an analogous cup, the free portion of which is very narrow and inserted around a large hilum, without the limit

between the aril and the funicle being marked by any contraction. This expansion is again found still narrower and less distinct from the umbilical cord in the genus Serjania; and, lastly, in some species of Cardiospermum (C. Halicacabum) we find nothing but the funicles thickened at their top without any trace of a free edge, whilst in others, with a less extended umbilical scar, a funicular expansion is seen which can be nothing but a rudiment of the aril. In these cases, of which I could furnish more in the same natural order, care must be taken not to confound the free part of the expansion of the umbilical cord, which alone is the aril, with any expansion of the same cord which, being extended over the seed, adheres to the testa, and which would only cover the surface of the hilum.

It is in consequence of inattention to this character of the aril, viz., its non-adherence to the testa, that this name has been given to the remarkable expansion of the top of the funicle found in beans, peas, and other Leguminous plants, as well as to umbilical scars when large and coloured, as in Cardiospermum, from which they have taken their generic name. The term aril does not apply to the thin fleshy lobed plate which, in Connarus and Omphalobium, is extended on the surface of the seed from the beginning of the raphe to about the middle of its length, and which is independent of the umbilical cord and of the hilum, being a parenchymatous layer of the testa to which it is intimately joined.

Now that we have gone through the principal modifications of the aril, it will be easy to recognise those appendages of the seed which have been wrongly called by this name, and which we shall next review in detail.

C. *Of the False Aril.*—If there is on seeds any envelope of doubtful nature it is certainly that which we are now going to notice; exterior with respect to the proper integuments, covering the exostome, and depending like the aril on the umbilical cord, it is distinguished from the aril by important characters, and constitutes a very anomalous false aril. Perhaps, indeed, the name of false testa would be more applicable to it, in consequence of its crustaceous texture,

and because, being completely developed before the expansion of the flower, it has always been described, not as an aril, but as a true testa. How can one, indeed, avoid taking for a proper integument the exterior envelope of the seeds of Opuntia, a hard, thick, reniform stone bordered by an elevated rim, and presenting no trace of any opening even when free from the pulp with which it is covered? It is, however, this very stone that I call a false aril or false testa, the origin and nature of which must be looked for in the early development of the ovules.

Those of Opuntia vulgaris, composed in a very young flower-bud of an ovoid nucleus and of two open integuments, end in thick funicles, with which they are perfectly continuous. Each of the latter, originally nearly straight, is gradually bent into a semicircle, and approaching at its base the point of the nucleus, forms a complete ring with the ovule. In that half of the ring which is lowest with respect to the ovule, arise, on the sides of the umbilical cord and at some distance from its base, two *rather concave* membranous expansions, which originate next the ovule and soon conceal the empty space comprised in the turn of the ring. The funicle and its two expansions then represent a sort of boat with a very large opening, and the cavity of which imperfectly conceals the ovule, which gets deeper and deeper into it. The latter soon disappears; the diameter of the opening remains the same, but seems to diminish in consequence of the very considerable growth of the ovule; and the side of the boat, distended by the young seed, soon forms for it a complete envelope. It is here that all the transformations of the ovule take place; from being orthotropal it becomes amphitropal, and changes, in this conversion, the direction of its micropyle, which, instead of being opposite the base of the funicle, is turned to the opposite side. Lastly, the accessory envelope of which we have been speaking, becoming thick and hard like a stone, and being covered on its outside with plenty of pulp, plays the part of a crustaceous testa with respect to the seed, and protects its thin proper integuments. But it is clear from what has now been stated, that this stone is nothing but a false testa; the cylindrical portion of the

funicle supporting it ought to leave upon it only a false umbilical scar; and lastly, the small hole of this envelope which represents the originally large opening of the boat can only be looked upon as a false micropyle. It is on the seed itself, *i. e.* below the false testa, that the true hilum and micropyle must be looked for.

Now that we have seen on the seeds of Opuntia an accessory envelope, it remains to show the difference between it and a true aril, in order to justify the name of false aril that I have given it. I shall not say that this envelope exists a long time before the expansion of the flower, whilst the aril only appears after impregnation; the Cytinus has shown us that this character of the aril is not altogether unexceptionable, as it was thought to be; but if it is true that the aril is an appendage of the umbilical cord, and an exterior leaf of the ovulary bud, such an organ cannot be the type of the false testa of Opuntia.

The latter, notwithstanding its intimate connexion with the funicle, is no more an appendage of it, or a modified leaf, than the flattened branches of Ruscus or of Xylophylla are true leaves.

It is not formed of a circular or unilateral expansion, like that of the Passion flowers, or of Turnera, but of two thin edges, which, produced from the two sides of the funicle, remind us of productions of a similar nature found on those axes called winged or bordered. Now that we know the origin of the crustaceous envelope which conceals the seed of Opuntia, it will be easy to understand that the portion of the umbilical cord originally curved into a ring is represented by the raised rim found at the contour of this envelope.

The micropyle is generally looked upon as a canal for impregnation, and the supposed existence of a tissue to conduct the fecundating matter is supported by curious and positive facts. When certain ovules, at the time of flowering, are seen invariably to bring their orifice to the same point of the ovary or of the placenta, this point may be properly considered as intended in a special manner to transmit the fecundating agent, and these conclusions have been confirmed by anatomy, which shows the existence of a peculiar tissue

extending from this point to the stigma. Other ovules, however, instead of bringing their exostome near the pericarp or the placenta, apply it to their funicle, which in this case either contains the conducting tissue or takes its place. If there is any doubt as to the latter statement, it is only necessary to recur to the ovules of Opuntia, which are, long before impregnation, completely covered by a thick accessory envelope, and the true micropyle of which, in no way corresponding with the orifice of the false testa called by us false micropyle, can have no direct communication with the exterior. It is clear that in this case the fecundating agent, whatever it may be, pollen-tube or fovilla, cannot pass directly from the pericarp to the ovule, since the latter is completely covered by the accessory envelope before mentioned. And since the ovule is in communication with the ovary only by the funicle, the latter alone can transmit fecundating matter to it.

Many genera of Indian Figs are so intimately allied to one another, that great analogy might be expected to be found between the integuments of their seeds. But such is not the case; the remarkable organisation of the seeds of Opuntia is not found in Epiphyllum, Rhipsalis, or Mammillaria, even when their fruit is ripe. Cereus peruvianus, the ovary of which I have only been able to observe sometime after flowering, has no trace of any accessory envelope on its ovules, although the funicles were at this time curved in the same way with respect to the ovules, as those of Opuntia before expanding into a membrane.

If the anomalous production just described has only been as yet found in a single genus of plants, such is not the case with the expansions of the exostome, the type of which is furnished by Euonymus. These, which are very common, and the nature of which has often been mistaken, deserve more especially the name of false arils, and coincide with certain modifications of the testa, which it will, perhaps, be useful to notice.

The testa, it is well known, often contains in its thickness very different layers of tissue. Sometimes its exterior is crustaceous, and the vascular network it contains is hidden, like the raphe, under one or more hard opaque plates. This

is to be found in Leguminosæ, Soapworts, Anonads, Dilleniads, and many other plants. In this case, I have frequently seen a true aril, but never an arillary expansion of the edges of the exostome. At other times, over one or two exterior plates of the testa, which are cartilaginous, or crustaceous, we find a layer, more or less thick, of parenchyma, in which the raphe and its ramifications are visible. This exterior layer, often described by Gærtner, under the name of epidermis, and considered in Euphorbiaceæ as an aril, by M. Roeper, is characteristic of the seeds of entire natural orders, as of Euphorbiaceæ, Malvaceæ, Butneriaceæ, Myristicaceæ, Tiliaceæ, Polygalaceæ, Hypericaceæ, Violaceæ, Linaceæ, Thymelaceæ, &c., &c.; and it is on these seeds that the expansions of the micropyle, which have often been confounded with those of the funicle, have been found. Between these two states of the testa, which are sometimes perfectly well marked, a number of intermediate stages are found, which make them run one into the other; Rhamnus, among many other examples, according to the correct observation of M. Ad. Brongniart, unites them both. Indeed, when I say that the expansion of the exostome is peculiar to those seeds which have a visible raphe on their outside, I do not mean that a true aril cannot exist on their testa, since Bixa, the seeds of which are covered with pulp, has, nevertheless, a rudimentary aril.

The seeds of Euphorbia, of Ricinus, and of many other Spurgeworts, have at the side of their point of attachment a fleshy, lenticular, or hemispherical excrescence, which, at an early period, attracted the attention of observers. Without saying anything as to its nature, Adanson described it as a fleshy tubercle; and Gærtner, after him, as a thick spongy hilum. This error of the German carpologist was soon followed by one of a more serious nature. Some botanists, no doubt undecided as to the value of the word aril, applied it to the caruncle of Euphorbia. M. Mirbel, however, in his excellent memoir on the ovules of Euphorbia Lathyris, cleared up all doubts as to the nature of this excrescence, and clearly showed it to be nothing but the thickened edge of the exostome. If we compare this fact with that we have already

seen in Euonymus, it will be easily seen that the caruncle of Euphorbia is, as it were, nothing but a rudiment of the more highly developed arillode of the Spindletree; and this analogy will be still more evident, when we shall have seen states of the false aril intermediate between these two. If the results to which I have been led, by applying the single fact of M. Mirbel to a certain number of plants, are at all interesting to botanists, I shall state that in so doing I have only followed the example of M. Aug. de St. Hilaire, who, in his *Morphologie* (p. 751), very positively noticed the relations between the caruncle of Euphorbias and those which render the seeds of Polygala so remarkable.

What at first seems very curious in the seeds of the latter genus, is the various forms and sizes of the caruncles in different species. Always next the hilum, but independent of the funicle, they are sometimes nothing but simple conical tubercles, tridentate or trifid at their base; one or two linear fleshy extensions sometimes proceed from this same base, and extend to a greater or less degree towards the chalaza, being applied to the surface or back of the seed. But, notwithstanding these variations in form, the caruncle is always found at that point of the seed to which the radicle corresponds, and the nearly constant direction of the latter towards the micropyle is sufficient to make us suppose beforehand that the opening of the integument is found on the excrescence itself, or rather that the latter is nothing but the dilated exostome. This also was observed by Aug. de St. Hilaire, and if the opinion of so profound a philosopher were not a sufficient guarantee for the exactness of the fact, I should state that I have clearly seen the micropyle at the anterior part of the caruncle of Polygala myrtifolia and speciosa. It is then, I think, quite clear that the caruncle of Polygala is completely analogous to that of Euphorbia, and this new point of resemblance between the seeds otherwise so similar of these two genera, explains better why Adanson brought them both together in his family of Tithymales.

In other Milkworts the caruncle is singularly modified; that of Comesperma is covered with long hairs which conceal the whole seed; the thick oily one of Badiera occupies the

whole lower half of the surface of the testa. These excrescences I have many reasons to think are analogous to those of Polygala, but not having myself seen the seeds of these two genera, I cannot be certain on this point.

Between the excrescences we have just examined and those found on the seeds of the Lasiopetaleæ and of several Bytneriads, the connection is very striking. There is the same position next the hilum, the same variations in form, the size and toothings, and the same fleshy consistence. In addition to these external resemblances, we may add, that in the latter plants, as in Polygala, the radicle is constantly next the point of insertion of the caruncle, and that this is independent of the umbilical cord. And lastly, to make the identity perfect, I may state that I have seen in two species of Commersonia, the micropyle scarcely visible and placed on the caruncle itself. I have not been able to repeat the same observations on the seeds of Seringia, Thomasia, Lasiopetalum, and of others having caruncles; but if we may judge from the figures of the latter given by M. Gay, there exist such analogies in form and especially of position between these excrescences and those of Commersonia, that I should hardly hesitate in regarding them as expansions of the exostome.

Let us remark before proceeding further, that the productions of the micropyle have hitherto appeared frequent in families not distantly related to one another. Now that, for example, many botanists have placed Spurgeworts among the Polypetalous orders, we cannot but see the near affinities which unite this order to Lasiopetaleæ, Butneriaceæ, and in short to the whole of those groups which compose Jussieu's order of Malvaceæ. In all these families, as in Euphorbiaceæ, the presence of a caruncle is combined in a constant manner with that of a layer of parenchyma which covers one or more crustaceous plates of the testa. But because this coincidence is always found, we must not therefore conclude that the layer of parenchyma cannot exist without a caruncle.

In the preceding examples the false aril has been as it were rudimentary; we shall now proceed to some of those cases in which it is found extending much more over the seed.

The anatropal ovules of Clusia flava are, in an expanded flower, remarkable for the existence of two membranous hoods, placed one over the other, which seem to proceed from the edges of the exostome, and extending round this opening, to cover, without any adherence, nearly a quarter of the young seed. These hoods have sinuated margins and are of unequal length, the upper one only covering about one half of the lower one, which is applied immediately to the proper envelope of the ovule. Have these unequal productions the same origin? Can the lower one be an extension of the primine beyond its exostome, and the upper and shorter one the rim of the endostome expanded into a membrane? We should answer in the affirmative to the latter question if we stopped at external appearances; but a mere section of the ovule made through the micropyle and the raphe is sufficient to show that both of these expansions proceed from the primine only, and that the endostome, which is very narrow, is not even thickened at its edges. We are thus obliged to admit, notwithstanding the singularity of the fact, that the external envelope of the ovule, though simple in the greatest part of its extent, is unlined beyond the exostome into two unequal expansions; and if I may be permitted to compare a leaf of the ovule with the less modified appendages composing the corolla, I should find examples of a similar process of unlining in the petals of Lychnis, Silene, and other Cloveworts, which have at the top of their unguis elegantly fringed lamellæ.

Whether the curious organisation just described is peculiar to Clusia, and to the single species which I have observed, or not, I leave to be decided by those who can examine other species of this genus, or of the natural order to which it belongs. But I do not doubt that the arillary cupule observed in Quapoya, Havetia, Renggeria, &c., is a false aril caused by the expansion of the exostome.

It will no doubt be remembered that the latter attains its largest size on the seeds of the large-leaved Spindletree. The details which I gave concerning this plant at the beginning of the present memoir, will enable me to dispense with a long description of a similar structure, found in other species of the same genus or of the same natural order.

Euonymus Europæus, Celastrus scandens and buxifolius have furnished me, for the organ in question, the same characters as the Euonymus; and I cannot help thinking that they would be also found in Maytenus, Polycardia, Pterocelastrus, and other genera of Spindletrees, in which an aril has been described.

The fleshy, laciniate envelope of the nutmeg, so often cited as an example of an aril, is inserted by a pretty large surface to that extremity of the seed to which the radicle points, and even adheres to the base of the raphe. The funicle, which is very short, is attached to the same place, so that the hilum is confounded with the areola of insertion of the accessory envelope, and the latter seems to be an expansion of the umbilical cord *i.e.* an aril. But we know from the Euonymus that the false aril can be intimately adherent to the funicle, and even to the base of the raphe, without the more for that losing its principal character, and that the micropyle, clearly visible on the arillary integument, distinguishes the latter from the productions of the funicle. I have not been able to examine a nut in a sufficiently good state to enable me to see the micropyle on the surface of its so called aril; but a very good reason induces me to consider the latter as an expansion of the exostome. In seeds, the testa of which is composed of two layers, the external being parenchymatous, and the internal crustaceous, the position of the micropyle can be distinguished on each; on the external layer by a narrow opening or a shallow depression, and on the internal one on the contrary by a small tumour, more or less pointed, and very finely perforated, directly corresponding with the external opening, so that the place of the latter can be judged of from that of the tumour, and *vice versâ*. Now, in the Nutmeg, the testa of which is composed of two very distinct layers, in the areola of insertion of the pretended aril, we find the little tumour which on the crustaceous layer of the testa represents the micropyle, and towards which, as I have said, the radicle is pointed; this laciniate envelope then, though called an aril, is nothing but an expansion of the exostome.

The mass inclosed within the testa or outer integument is

still called the *nucleus;* and consists either of *albumen* and *embryo,* or of the latter only.

The *albumen* (*perispermium,* Juss.; *endospermium,* Rich.; *medulla seminis,* Jungius; *secundinæ internæ,* Malpighi) (Plate VI. fig. 5. *a,* 1. *a,* 9. *a,* &c.), when present, is a body inclosing the embryo, and interposed between it and the integuments of the seed when there are any: it is of different degrees of hardness, varying from fleshy to bony, or even stony, as in some palms. It is in all cases destitute of vascularity, and has been usually considered as the amnios in an indurated state: but Brown is of opinion that it is formed by a deposition or secretion of granular matter in the cellules of the amnios, or in those of the nucleus itself.

The albumen is often absent, is frequently much smaller than the embryo, but is also occasionally of much greater size. This is particularly the case in monocotyledons, in some of which the embryo scarcely weighs a few grains, while the albumen weighs many ounces, as in the cocoa-nut. It is almost always solid, but in Anonads and Nutmegs it is perforated in every direction by dry cellular tissue, which appears to orginate in the remains of the nucleus in which the albumen has been deposited: in this state it is said to be *ruminated.*

The best account of albumen yet published, is that of Schleiden and Vogel, of which the following is the substance:—

1. *On the Formation of Albumen.*—The essential parts of the ovule are the nucleus and embryo sac, which are never absent. In the embryo sac, a portion of cellular tissue is often developed and again absorbed; this is Mirbel's quartine. In seeking for albumen, the positions in which it might be expected to be found are, 1, in the integuments, 2, the nucleus, 3, the embryo-sac, 4, the region of the chalaza. It is, however, never found in the integuments, but in all other parts. In Monocotyledons, albumen is mostly found in the embryo-sac, reducing the walls of the nucleus, by pressure, to a thin membrane. It is difficult to say whether the membrana interna of the ripe seed is formed from the integumentum internum of the ovule, from the membrana nuclei, or from

a combination of both. It may be sometimes formed from each. In the process of growth the embryo-sac becomes filled with cellular tissue, which produces the albumen. Examples may be seen in Philydrum lanuginosum, also in all Arads, Grasses, Sedges, Lilyworts, Palms, &c. Amomals are an exception, for excepting Canna, they develop their albumen in the nucleus, as in Maranta gibba. The development of Canna is altogether peculiar. The albumen is developed in the region of the chalaza, and although five layers can be distinguished they can none of them be identified. In Dicotyledons the growth of the albumen is not so uniform, in these whole groups of families being characterised by its presence or absence. The albumen formed in the embryo-sac is called *Endosperm*, while that formed in the nucleus is called *Perisperm*. When the embryo-sac does not fill the nucleus, and the embryo does not fill the former, both perisperm and endosperm are developed, as seen in Waterlilies (Nymphæaceæ) and Watershields (Hydropeltideæ); also in Peppers. In Chelidonium majus, the endosperm is alone developed; and this is the case with all Papaveraceæ, Ranunculaceæ, Umbellifers and Cinchonads. The perisperm is probably developed in all families which have what is called *albumen centrale*.

2. *On the Structural Relations and Extent of the Albumen.*—In most cases the albumen has the form of the seed on a reduced scale. A remarkable deviation is seen in Convolvulus. The endosperm consists of a double spindle-shaped body, with two wing-like appendages, between which the cotyledons are placed. In many of the Figworts (Scrophulariaceæ) the embryo-sac forms little cavities or bags, which, in the ripe seed, remain as appendages to the albumen. Albumen, as well as all other parts of plants, consists essentially of cellular tissue, the cells of which have contents. Cytoblasts are found only occasionally in the cells of albumen, but may be seen very well in Zea Mays. The cells present all the varieties of ordinary parenchym, but never any spiral structure. The walls of the cells are generally thin, simple, without evident configuration, as in the case of the *albumen farinaceum* and *carnosum*. The walls are often thick and grown together, so that the cells look as if they were cut out of a homogeneous

mass, as in the *albumen oleosum* and *corneum*. In Cinchonads there are thin spots in the horny albumen, as though pores were forming; the same is seen in the horny albumen of some Palms. In the thin-walled cells pores are very evident. With regard to the general arrangement of the cellular tissue, it has a ray-like texture, from its being developed from the walls of the sac towards the embryo, or if that is very small towards the centre of the albumen. With regard to the contents of the cells of albumen, they do not differ much from those of parenchym in general. In Alpinia Cardamomum, formless masses are observed in the cells of the perisperm. Between the cells of Pothos rubricaulis are found larger cells containing some crystallised salt.

3. *On the Albumen of Leguminous Plants.*—If any one should examine the seeds of Cassia, Gleditschia, and Tetragonolobus, he would find it difficult to account for the fact that in recent times albumen had been denied to Leguminous plants. Gærtner originally made exceptions to the statement that they had no albumen; it was confined, by Jussieu, to the orthoblastic genera. De Candolle called the albumen of these plants an *Endopleura tumida*, and most botanists have followed him. Guillemin and Perrottet, in the *Flora of Senegal*, sometimes call this substance albumen, sometimes Endopleura tumida. In order to investigate this subject, and arrive at the following conclusion, more than 300 different kinds of seeds of Leguminous plants have been examined.

a. Formation and Presence.—The ovule of Tetragonolobus purpureus has two integuments covering the nucleus. The embryo-sac developes itself in the vicinity of the micropyle and grows from thence out towards the chalaza. In Brachysema undulatum, the integuments and nucleus are not developed till after the embryo-sac and embryo appear, and the internal membrane disappears with the absorption of the nucleus. In Tetragonolobus the nucleus is first absorbed, then the internal membrane, the entire length of which disappears at the same time. The embryo, in its development, constitutes a transition to that irregular form seen in Lupinus. Ordinarily that part of the pollen tube which has projected into

the embryo-sac becomes changed into a part of the embryo; but in Lupinus only a part of the tube becomes organised with the embryo, the remaining portion forming a little cord-like body, called by Mirbel the suspensor. As the embryo-sac extends, it forms cells out of the mucous and saccharine solution in its inside, the cells being developed around the cytoblasts in the manner described by Schleiden. At the same time this cellular tissue is forming the embryo increases in size, and either absorbs this or presses it more or less together; in the latter case it is the seat of the deposit of albumen. This is often the case, and in most instances the nucleus is entirely absorbed. Hence the albumen of Leguminous plants is endosperm; its greater or smaller thickness depends on the greater or smaller size of the embryo. In the whole family there is a very decided fluctuation in the presence and quantity of this albumen; so that the suggestion of Braun to distinguish the genera of Mimoseæ by it, is quite untenable. In fact there are some very good genera, as Lupinus, in which some species have it, and some have none. Lupinus tomentosus and L. macrophyllus both have albumen, L. tuberosus none. In Ononis altissima, it is scarcely to be seen, whilst in O. aculeata it is very abundant. Æschynomene fluminensis has a maximum, whilst Æ. podocarpa has a minimum. Many more examples would undoubtedly occur in large genera, as Trifolium, &c. In Acacia some species have abundance, others none. But if the existence of albumen fluctuates, much more do its relative quantity and its relative position to the embryo. Its development is least decisive in the whole family on the edges of the cotyledons; in Papilionaccæ least at the hilum and in greatest quantity between the radicle and cotyledons, and in the commissure between the cotyledons; in both of which places it may be beautifully seen in Scorpiurus sulcatus, yet it is sometimes wanting here when it appears on the sides of the cotyledons. The quantity of albumen has been supposed to be in an inverse proportion to the size of the plumule, but this is not a rule,

even in the genera, to which it was supposed to apply. Nor is a large quantity of albumen accompanied with simple leaves of the plumule, as was supposed by Braun. In opposition to the oft-repeated assertion of Adanson, Jussieu, and De Candolle, it is found that all the principal divisions of Leguminous plants, except Swartzieæ and Geoffreæ, of which only one seed was examined, possess albumen.

b. Structure.—If a layer of albumen is cut, it is transparent, almost of a horny consistence, becomes gelatinous in water, is almost insipid to the taste, and consists of vegetable jelly (P. pflanzengallerte of Schleiden) or mucus (P. pflanzenschleim of Berzelius). In most cases the colour is whitish, in some beautifully white, as Cytisus, Kennedya, &c. When it is transparent, so long as the testa remains on, it has a variety of colours. In Bauhinia microphylla, the albumen was of a wood-yellow colour. Where the albumen is tolerably well developed, three layers are observed; first, that next the testa with regular cells, well defined walls, and ordinarily granular mucous contents: the cells are arranged in only one row. This layer is well seen in Astragalus hamosus, Sesbania cannabina, &c. In the second layer there is a number of variously formed cells, constituting the great bulk of the albumen; these are succeeded by a third row placed next the cotyledons, which are small and without granular contents. In the middle layer the cells have either very sharply defined walls, or they are lost in jelly. The former are most common in Papilionaceæ, the latter in Cæsalpineæ. When the walls of the cell are evident, jelly is found in the inside of the cell, often obstructing the entrance of the light, as in Sesbania cannabina, &c., it is entirely obstructed in Securigera coronilla. Frequently the cavity of the cell presents a star shape, from the formation of pores in the jelly, or gelatine, as in Cytisus, Laburnum, &c. Intercellular spaces are seen in Amorpha fruticosa, &c., which are also filled with jelly. These form a transition to those in which the cells are entirely

embedded in jelly, as Gleditschia triacanthos. The walls are not to be distinguished but by dropping on them sulphuric acid, by which means the jelly is dissolved out. The interior of the cells is filled with mucus (Schleim), a term used to distinguish it from jelly and starch. This mucus is composed of globules, which are coloured brown yellow by tincture of iodine. In Cathartocarpus fistula resinous globules were found, and in Mimosa pudica, crystals in the same position. This jelly or gelatine between the cells, seems to be identical with Mohl's intercellular substance, and it may be conjectured to be the basis from which the cells of the albumen themselves are formed.

The *embryo* (or *corculum*) (Plate VI. fig. 1. *b*, &c.) is a fleshy body occupying the interior of the seed, and constituting the rudiment of a future plant. In most plants one embryo only is found in each seed. It nevertheless occurs, not unfrequently, that more than one is developed within a single testa, as occasionally in the Orange and Hazel nut, and commonly in Conifers, Cycas, the Onion, and the Mistletoe. Now and then a union takes place of these embryos.

It is distinguished into three parts; viz., the *radicle* (Plate VI. fig. 2. *b*, &c.) (*rhizoma* or *rostellum*); *cotyledons** (fig. 2. *a*, &c.); and *plumule* (or *gemmule*) (fig. 2. *c*.); from which is also by some distinguished the *cauliculus* or *neck* (*scapus*, *scapellus*, or *tigelle*). Mirbel admits but two principal parts; viz., the cotyledons, and what he calls the *blastema*, which comprises radicle, plumule, and cauliculus.

The *direction* of the embryo is either *absolute* or *relative*. Its absolute direction is that which it has independently of the parts that surround it. In this respect it varies much in different genera; it is either straight (Plate VI. fig. 5.), arcuate (fig. 9.), falcate, uncinate, coiled up (fig. 8.) (*cyclical*), folded up, spiral (fig. 19.), bent at right angles (Plate V. fig. 28.) (*gnomonical*, Link), serpentine, or in figure like the letter S (*sigmoid*).

* Cotylēdon (κοτυληδών), not cotylĕdon as it is often called.

Its relative position is determined by the relation it bears to the chalaza and micropyle of the seed; or, in other words, upon the relation that the integuments, the raphe, chalaza, hilum, micropyle, and radicle bear to each other. If the sacs of the ovule are in no degree inverted, but have their common point of origin at the hilum, there being (necessarily) neither raphe nor chalaza visible, the radicle will in that case be at the extremity of the seed most remote from the hilum, and the embryo *inverted* with respect to the seed, as in Cistus, Urtica, and others, where it is said to be *antitropal.* But if the ovule undergoes the remarkable extension of one side already described in speaking of that organ, when the sacs are so inverted that their orifice is next the hilum, and their base at the apex of the ovule, then there will be a raphe and chalaza distinctly present; and the radicle will, in the seed, be at the end next the hilum, and the embryo will be erect with respect to the seed, or *orthotropal,* as in the Apple, Plum, &c. On the other hand, supposing that the sacs of the embryo suffer only a partial degree of inversion, so that their foramen is neither at the one extremity nor the other, there will be a chalaza and a short raphe; and the radicle will point neither to the apex nor to the base of the seed, but the embryo will lie, as it were, across it, or be *heterotropal,* as is the case in the Primrose. When an embryo is so curved as to have both apex and radicle presented to the hilum, as in Reseda, it is *amphitropal.* It is, however, becoming customary to apply to the seed the same names as those used in expressing the modifications of the ovule; this will probably become the universal practice, and then all terms referring to the position of the embryo will become superfluous.

In the words of Gærtner an embryo is *ascending* when its apex is pointed to the apex of the fruit; *descending,* if to the base of the fruit; *centripetal,* if turned towards the axis of the fruit; and *centrifugal,* if towards the sides of the fruit: those embryos are called wandering, or *vagi,* which have no evident direction.

The *cotyledons* are generally straight, and placed face to face; but there are numberless exceptions to this. Some are separated by the intervention of albumen (Plate VI. fig. 11.);

others are naturally distant from each other without any intervening substance. Some are straight, some waved, others arcuate or spiral. When they are folded with their back upon the radicle, they are called *incumbent;* if their edges are presented to the same part, they are *accumbent;* terms chiefly used in speaking of Crucifers.

Upon certain differences in the structure of the embryo, modern botanists have divided the whole vegetable kingdom into three great portions, which form the basis of what is called the natural system. These are, 1. Dicotyledons; 2. Monocotyledons; and, 3. Acotyledons. In order to understand exactly the true nature of the embryo in each of these, it will be requisite first to describe it fully as it exists in dicotyledons, and then to explain its organisation in the two others.

If a common DICOTYLEDONOUS embryo (Plate VI. fig. 2.), that of the Apple for example, be examined, it will be found to be an obovate, white, fleshy body, tapering and solid at the lower end, and compressed and deeply divided into two equal opposite portions at the upper end; the lower tapering end is the *radicle,* and the upper divided end consists of two *cotyledons.* Within the base of the cotyledons is just visible a minute point, which is the *plumule.* The imaginary line of division between the radicle and the cotyledons is the *caulicule.* If the embryo be placed in circumstances favourable for *germination,* the following phenomena occur: the caulicule will extend so as to separate the cotyledons from the radicle by an interval, the extent of which varies in different plants; the radicle will become elongated downwards, forming a little root; the cotyledons will either elevate themselves above the earth and unfold, or, remaining under ground, will part with their amylaceous matter and shrivel up; and the plumule will lengthen upwards, giving birth to a stem and leaves. Such is the normal or proper appearance of a dicotyledonous embryo.

The *exceptions* to it chiefly consist, 1. in the *cohesion* of the cotyledons in a single mass, instead of their unfolding; 2. in an increase of their *number;* 3. in their occasional *absence;* and, 4. in their *inequality.*

A *cohesion* of the cotyledons takes place in those embryos which Gærtner called *pseudomonocotyledonous*, and Richard *macrocephalous*. In the Horsechesnut, the embryo consists of a homogeneous undivided mass, with a curved horn-like prolongation, of one side directed towards the hilum. If a section be made in the direction of the axis of the horn-like prolongation, through the whole mass of the embryo, a slit will be observable above the middle of the horn, at the base of which lies a little conical body. In this embryo the slit indicates the division between the two bases of a pair of opposite confluent cotyledons; the conical body is the plumule, and the horn-like prolongation is the radicle. In Castanea nearly the same structure exists, except that the radicle, instead of being curved and exserted, is straight, and inclosed within the projecting base of the two cotyledons; and in Tropæolum, which is very similar to Castanea in structure, the bases of the cotyledons, are slit into four little teeth inclosing the radicle. The germination of these seeds indicates more clearly that the cotyledonary body consists of two and not of one cotyledon; at that time the bases of the cotyledons, which had been previously scarcely visible, separate and lengthen, so as to extricate the radicle and plumule from the testa, within which they had been confined.

Mr. Griffith states that in Careya herbacea, "The fleshy body which constitutes the entire mass of the seed, after the removal of the testa, consists of a peripheral fleshy mass and a central subulate body firmly adherent with it, of similar texture, and having its apex directed towards one side of the hilum. At the opposite extremity the outer mass is surmounted by a number of colourless scales, surrounding and concealing other more minute scales, which occupy the extremity of the central subulate body. There are no traces of cotyledonary division, and the subulate body, excepting at its divided upper extremity, is continuous with the rest of the fleshy mass. The commencement of the germination takes place while the seeds are still inclosed in the fruit. The integument is ruptured longitudinally, and generally with some degree of regularity along the apex; from this opening are exserted pale greenish scaly leaf-like bodies, consisting

first of those which surmount the outer mass, and subsequently of the divided termination of the central subulate body. As this latter increases in length, it is seen to terminate in a green convolute leaf, in the axilla of which is placed another very rudimentary one. At this period the extremity of the subulate body next the hilum has also become exserted, and forms a subulate fleshy and undivided projection. Into this the cellular tissue of the fleshy body passes, although there is a faint line of demarcation between the two.

"The absolute nature of the outer fleshy part," Mr. Griffith observes, "can only be determined by pursuing the development of the ovula. The nature of the subulate body is evident; it is the root, the true plumula being the minute scaly body at its distal end. The root points, as it should do, towards the side of the hilum, the situation, in fact, of the foramen. At the collar it is continuous with the plumula, and laterally with the outer fleshy mass; which ought, therefore, to be cotyledonary, and taking it to be so, might be explained, by supposing the cotyledons to be affixed in a peltate manner, and united into a solid mass."

In *number* the cotyledons vary from two to a much more considerable number; four occur in Borageworts, Crucifers, and elsewhere; in Conifers they vary from two to more than twelve.

Instances of the *absence* of cotyledons occur, 1. in Cuscuta (Plate VI. fig. 19.), in which they may be supposed to be deficient, in consequence of the absence of leaves in that genus; 2. in Butterworts (Lentibulariaceæ); and, 3., in Cyclamen, in which the radicle enlarges exceedingly. To these a fourth instance has by some been added in Lecythis, of which Richard gives the following account:—The kernel is a fleshy almond-like body, so solid and homogeneous that it is extremely difficult to discover its two extremities until germination takes place: at that period one of the ends forms a little protuberance, which subsequently bursts through the integuments of the seed and extends itself as a root; the other end produces a scaly plumule, which in time forms the stem. The great mass of the kernel is supposed by Richard to be an enlarged radicle. I, however, see no reason for

calling the two-lobed part of the embryo (Plate VI. fig. 17. *c*) a plumule, instead of cotyledons.

An *inequality* of cotyledons is the most unusual circumstance with dicotyledons, and forms a visible approach to the structure of monocotyledons: it occurs in Trapa and Sorocea, in which they are extremely disproportionate. In Cycas they are also rather unequal; but in a much less degree.

A case has been mentioned by Mr. Griffith, in Cryptocoryne spiralis, of the cotyledon being cut off, after being formed. "The separation," he says, "of the chief part of that portion, which is evidently from its direction the cotyledon, is most remarkable, and forms another exception to a general law. I allude to the very general absolute necessity of the cotyledons. I am, however, inclined to think, from this and some other instances, that the presence of a highly developed plumula occasionally obviates this necessity. The separation in question appears to depend upon some constriction exerted upon the cotyledon by the apex of the nucleus." (*Linn. Trans.*, xx. 271.)

The embryo of MONOCOTYLEDONS (Plate VI. fig. 1, B, &c.) is usually a solid, cylindrical, undivided, homogeneous body, slightly conical at each extremity, with no obvious distinction of radicle, plumule, or cotyledons. In *germination* the upper end swells and remains within the testa (*fig.* 10. c *b*, &c.); the lower lengthens, opens at the point, and emits one or more radicles: and a thread-like green body is protruded from the upper part of the portion which is lengthened beyond the testa. Here the portion remaining within the testa is a single cotyledon; the body which lengthens, producing radicles from within its point, is the cauliculus; and the thread-like protruded green part is the plumule. If this is compared with the germination of dicotyledons, an obvious difference will be at once perceived in the manner in which the radicles are produced: in monocotyledons they are emitted from within the substance of the radicular extremity, and are actually sheathed at the base by the lips of the passage through which they protrude; while in dicotyledons they

appear at once from the very surface of the radicular extremity, and consequently have no sheath at their base. Upon this difference Richard proposed to substitute the term *Endorhizæ* for monocotyledons, and *Exorhizæ* for dicotyledons. Some consider the former less perfect than the latter: endorhizæ being *involute*, or imperfectly developed: exorhizæ *evolute*, or fully developed. Dumortier adds to these names *endophyllous* and *exophyllous*; because the young leaves of monocotyledons are evolved from within a sheath (*coleophyllum* or *coleoptilum*), while those of dicotyledons are always naked. The sheath at the base of the radicle of monocotyledons is called the *coleorhiza* by Mirbel. Another form of monocotyledonous embryo is that of Arads and their allies, in which the plumule is not so intimately combined with the embryo as to be undistinguishable, but is indicated externally by a little slit above the base (Plate VI. fig. 6. B. *e*), within which it lies until called into development by germination.

Mr. Griffith describes a most singular exception to the usual monocotyledonous structure in Cryptocoryne spiralis:—"The embryo is of a singular shape. Its descending portion, or cotyledon, is clavate, and nearly entirely inclosed within the nucleus; the inclosed part separating with that body exceedingly readily, and subsequently, about the same time of dehiscence of the fruit, spontaneously. The tissue of the inclosed part is firm, and more dense than the short uninclosed part. The exserted portion of the embryo consists exclusively of the base of the cotyledon, of a fleshy, firm, plano-convex body. The plane part is depressed towards the centre, to which the base of the cotyledon is attached. From one side of this the radicle projects, which is still conical and acute, and is always directed from the placenta, and generally outwards, but often laterally, and always more or less downwards. The circumference of the convex part is entirely occupied by the processes, constituting an enormously developed plumula. These are densely imbricated, intermixed with abortive and rudimentary ones, and of immense length, especially the outermost, which are about one inch long. They are all subulate, with the exception of the two or three

innermost ones, which resemble rudimentary leaves, and are divided into a limb, which is convolute, and a petiole, which is likewise convolute, the innermost inclosing in its fold an extremely minute rudimentary leaf. The outermost are the narrowest, the bases, as we proceed inwards, becoming gradually dilated. They are all deflexed and tortuous, especially the outer ones. Their extreme apices are invariably brown, and, as it were, sphacelated. The colour is green, increasing in depth as we proceed inwards, the convolute laminæ of the innermost being of a rather deep tint. These processes are furnished with vessels, but their chief bulk is cellular, the cells containing a considerable number of green globules. They are, with the exception, perhaps, of the outermost, furnished with stomata. These bodies, however, appear to be perfect in the interior processes only. They are most abundant towards the apices of these, especially on the portion which corresponds to the lamina of the perfect leaf, and are perhaps altogether wanting towards or near their dilated bases. The cells of the cotyledon, as well as of the processes of the plumula, in an early stage of their development, abound in active molecules, which have, both in and out of the containing cells, an exceedingly rapid oscillatory motion. It is obvious, from the universal presence of these corpuscles during the formation of tissue, that they play an important part in this most obscure process." (*Linn. Trans.* xx.)

All such *exceptions* ought, like those of dicotyledons, rather to be called remarkable modifications. Much stress has been laid upon some of them by several writers, who have thought it requisite to give particular names to their parts. It, however, appears more advisable to explain their analogies without the unnecessary creation of new and bad names. In Grasses (Plate VI. fig. 4.) the embryo consists of a lenticular body lying on the outside of the base of the albumen on one side, and covered on its inner face by that body, and on its outer face by the testa: if viewed on the face next the testa, a slit will be observed of the same nature as that in the side of the embryo of Araceæ; within this cleft a small conical projection is discovered, pointing towards the apex of the seed. If the embryo be then divided vertically through the

conical projection, it will be seen that the latter (*c*) is a sheath including other little scales resembling the rudiments of leaves; that that part of the embryo which lies next the albumen (*d*), and above the conical body, is solid; and that the lower extremity of the embryo (*e*) contains within it the indication of an internal radical, as in other monocotyledons. In this embryo it is to be understood that the conical projection is the *plumule;* that part of the embryo lying between it and the albumen, a single scutelliform *cotyledon;* and the lower point of the embryo, the *radicle.* In Wheat there is a second small cotyledon on the outside of the embryo, inserted a little lower down than the scutelliform cotyledon. This last is called *scutellum* by Gærtner, who thought it of the nature of vitellus. Richard considered the scutelliform cotyledon a particular modification of the radicle, and called it *hypoblastus;* the plumule a form of cotyledon, or *blastus;* the anterior occasional cotyledon a peculiar appendage, or *epiblastus;* and the radicle a protuberance of the caulicule, or *radiculoda.* He further, in reference to this opinion, termed embryos of this description *macropodal.* In these ideas, however, Richard was wrong, as is now well known.

From what has been stated, it is apparent that dicotyledons are not absolutely characterised by having two cotyledons, nor monocotyledons by having only one. The real distinction between them consists in their endorhizal or exorhizal germination, and in the cotyledons of dicotyledons being opposite or verticillate, while they are in monocotyledons solitary or alternate. Some botanists have, therefore, recommended the substitution of other terms in lieu of those in common use. Cassini suggests *isodynamous* or *isobrious* for dicotyledons, because their force of development is equal on both sides; and *anisodynamous* or *anisobrious* for monocotyledons, because their force of development is greater on one side than on the other. Another writer, Lestiboudois, would call dicotyledons *exoptiles,* because their plumula is naked; and monocotyledons *endoptiles,* because their plumule is inclosed within the cotyledon; but there seems little use in these proposed changes, which are, moreover, as open to objections as the terms in common use.

In the *Library of Useful Knowledge,* the following explanation of the analogy between the embryo of monocotyledons and dicotyledons has been given :—

"1. The embryo of an Arum is like that of a Palm, only there is a slit on one side of it through which the plumule easily escapes; 2. in Rice (Oryza) this slit is very much lengthened and widened; 3. in Barley the plumule projects beyond the slit, leaving a flat cotyledon on one side; and, 4., in Wheat the embryo has the structure of Barley, with this most important exception, that at the base of the plumule in front there is a rudimentary cotyledon, alternate with the large flat one on the opposite side of the plumule. Hence we are to infer that the monocotyledonous embryo of a Palm *is analogous to that of a dycotyledon, of which one of the cotyledons is abstracted, and the other rolled round the plumula and consolidated at its edges.* And this is the view that must be taken of the monocotyledonous embryo in general, all the modifications of which seem reducible to this standard.

"Thus in Sea-wrack (Zostera marina), of which the embryo is an oblong almond-shaped body with a cleft on one side, in the cavity of which a long flexuose process is placed, the latter is the plumule, and the former at one end the cotyledon, and the radicle at the other; in Ruppia maritima, whose embryo is an oblong body, cut suddenly off at one end, on which a sort of curved horn crouches, the latter is the plumule, and the former chiefly cotyledon; and so in Frog-bit (Hydrocharis morsus ranæ), the embryo of which is an oblong fleshy kernel with a hole on one side, in which there lies a short cylinder, the latter is the plumule, and the former the cotyledon."

M. Adrien de Jussieu has examined this theory with much ability. By tracing the development of the monocotyledonous embryo, he found that in reality the plumule is enwrapped by the lower portion only of the cotyledon, and therefore he would modify the theory accordingly. "La Théorie de M. Lindley n' est donc vraie que pour la partie inférieure ou gaîne du Cotyledon, la seule qui s'enroule autour de la plumule; et la première feuille de la plante monocotylédonée ne se comporte pas autrement que chacune des autres, dont

la gaîne enveloppera de même l'ensemble des feuilles suivantes avant leur développement." (*Annales des Sciences,* 2nd ser. xi. 350.)

It is gratifying to find a morphological speculation confirmed upon such authority. I say *confirmed,* because, in fact, M. de Jussieu admits all that is essential in the theory as originally propounded. I certainly did not mean that the whole cotyledon of a monocotyledonous embryo was necessarily rolled from end to end around the plumule, but that the whole or a part was in that condition.

The ACOTYLEDONOUS embryo is not exactly, as its name seems to indicate, an embryo without cotyledons; for, in that case, Cuscuta would be acotyledonous. On the contrary, it is an embryo which does not germinate from two fixed invariable points, namely the plumule and the radicle, but indifferently from any point of the surface; as in some Arads, and in all flowerless plants. See Mohl, *Bemerkungen über die Entwicklung und den Bau der Sporen der Cryptogamischen Gewächse:* Regensb. 1833.

16. Of Naked Seeds.

By naked seeds has been understood, by the school of Linnæus, small seed-like fruit, like that of Labiates, Borageworts, Grasses, and Sedges. But as these are distinctly covered by pericarps, as has been already shown, the expression in the sense of Linnæus is incorrect, and is now abandoned. Hence it has been inferred that there is no such thing in existence as a naked seed; that is to say, a seed which bears on its own integuments the organ of impregnation.

To this proposition botanists had assented till the year 1825, when Brown demonstrated the existence of seeds strictly naked: that is to say, from their youngest state destitute of pericarp, and receiving impregnation through their integuments without the intervention of style or stigma, or any stigmatic apparatus. That learned botanist has demonstrated that seeds of this description are uniform in Conifers and Cycads, in which no pericarpial covering exists. But we

have no knowledge at present of such an economy obtaining in other plants except Taxads and Jointfirs (Gnetaceæ) as a constant character. It does, however, happen, as the same observer has pointed out, that in particular species the ovary is ruptured at an early period by the ovules, which thus, when ripe, become truly naked seeds: remarkable instances of which occur in Ophiopogon spicatus, Leontice thalictroides, and Peliosanthes Teta. The seeds are almost uncovered after the ovary begins to swell, in Reseda; and in the common Vine the grapes are occasionally ruptured, allowing their seeds to protrude and *ripen*.

17. The Comparative Anatomy, or Morphology of the Floral Organs in Flowering Plants.

From what has been said in the preceding pages it will have become obvious that the flower, and all the parts that belong to it, are in reality collections of organs originally the same in nature as the leaf, arranged upon the same plan, and modified according to the different purposes they are to serve. This being so, the apparently complicated apparatus of a flower is in reality an arrangement of the simplest kind; and the infinite diversity observable in the blossoms of plants is explicable upon a few general principles.

Zuccarini has well observed that we should never lose sight of the great fact, that in Nature there is a paucity in the number of forces, but a prodigious variety in their adaptation to the same object. In no department of the organic world is this more manifest than in the Vegetable Kingdom; so that the difficulty we now experience is not how these things should be, but how it has happened that they were so long unseen.

The earliest philosophers who adopted what are now called Morphological views, reasoned *à priori*, generalising from an exceedingly small supply of facts. Nevertheless, their views have been proved to be correct, by the unerring testimony of progressive development. This is sufficiently proved by the following very instructive cases:—

A. *The progressive development of Mallow-worts* (Malvaceæ),

by Duchartre.—The calyx, which at a later period becomes monophyllous with five divisions, appears at first in the form of a continuous rim, surrounding the central mass of the flower, bounded by a large convex tubercle having no distinction of parts. This border soon sends off five small festoons, which correspond to the five sepals thus united at the base from the commencement. This mode of formation is found in the envelopes of all those flowers having a monophyllous calyx or corolla, the development of which the author has had an opportunity of studying. The petals and stamens may be subsequently distinguished and are simultaneously developed, so that it is well to trace their evolutions together. Soon after the appearance of the calyx, the margin of the central tubercle becomes raised into five smaller tubercles, which are rounded, alternating with the segments of the calyx, and thus representing the floral whorl which immediately succeeds it. Each of these tubercles soon appears like two in juxtaposition, its development ensuing more rapidly at the two sides than in the median line: and thus, instead of five small primitive eminences, we have five pairs. Nearly at the same time a slight transverse fold appears below and outside of each of these five projections; this appears to be another appendage of the tubercle, which, at first single, subsequently becomes double. The fold becomes the petal; the tubercles become stamens. Hence the petals and stamens here belong to one and the same group of organs developed from a base which is common to that spot which in most flowers is occupied by the petal alone.

The petal in its further development, which is generally rather slow, much more so than that of the stamens, does not become doubled, and gives no other indication of this tendency except in its more or less bilobate summit.

Not so, however, with the stamens; for shortly after the first ten staminal tubercles have become distinct, we find that a formation perfectly similar to the first is produced. Five new pairs of tubercles opposite to the first, appear in a more internal circle; then a third arranged concentrically, and consisting of ten other tubercles; then a fourth, so that the total number is successively doubled, tripled, and quadrupled.

We thus have ten radiant series, opposed in pairs to the petals, and supported upon a common base, which is frequently cut into five corresponding lobes, more or less marked. At a little later period, each of these tubercles, continuing to grow more at the sides than in the median line, is itself divided into two, and we find that four parallel series become substituted for the two before each petal, and the total number is a second time doubled. The same occurs in those flowers which have very numerous stamens; but there is a slight difference in those in which they exist in less numbers. When either fewer concentric rows are formed, or each of these rows stops at that period at which the pairs are simple and not doubled, or within the first pairs, a single tubercle only is formed; this is slightly lateral and oblique; then another still more internal and on the opposite side, so that within the first pair we find only isolated tubercles, sent off alternately, first from one side, then from the other, in a zig-zag direction. In all cases, there are invariably five systems of stamens opposite to the petals.

During these changes, the small common tube, to which all these organs are attached, continues to elongate, raising these concentric formations so as to produce a system of stages arranged one above the other; and, although they enlarge at the same time, they do not do so in the same proportion. The organs which enlarge do not then find sufficient room to lie side by side in regular and concentric circles; they become rather confusedly mixed, and the original symmetry becomes less and less apparent. When they have arrived at a certain degree of development, each of the tubercles shrinks up at the base into a minute filament which becomes more and more elongated. Each also becomes marked by a median furrow, and buried within two cells which subsequently fuse into a single one. In short, these are so many reniform, unilocular anthers, which tend more and more to assume their definite form.

In several species M. Duchartre has observed an ulterior change, from which a new increase in the number of stamens results. Several of them are curved into a horse-shoe form, and terminate by becoming divided into two by a constric-

tion of the summit of their curve—a constriction which ends by forming a complete solution of continuity; this, extending from above downwards, also divides the filament which was at first simple, into two corresponding to the anthers thus formed. This is a true duplication.

This term would apply with less accuracy to the anterior formations, from which the multiplication of the stamens has resulted; for we may say, that at each of these changes they have doubled rather than multiplied. Be this as it may, we have clearly five groups of organs alternating with the five leaflets of the calyx, each comprising a petal and several stamens, supported upon a base which is common and simultaneously developed. This is the whorl which is within and alternate to the calyx, and which is ordinarily called the corolla, with this difference, that here each petal is replaced by a group or bundles of organs.

One of the reporters on M. Duchartre's observations is of opinion, that in those flowers which have stamens double in number to the petals, whenever the stamens of the external row are opposed to the petals (and this is most frequently the case) they do not constitute a distinct whorl, but form a part of that of the corolla. The development of the flower of the Mallow-worts supports this opinion, exhibiting each of the petals, opposed, not to a stamen, but to an entire bundle. It is added, that such appears to be the most common symmetry in polyadelphous polypetalous flowers, as is seen in so many Myrtaceæ, Hypericaceæ, &c., where the bundles, which are perfectly distinct, are opposite to the petals.

What has become of the normal whorl of the stamens,—that which should alternate with the petals? M. Duchartre discovers this in the five terminal lobes of the staminal tube, situated upon a plane anterior to that of the filaments, alternating with their five groups,—lobes which we observe in many of the Malvaceæ, although they are barely perceptible, and even are entirely wanting in many others. MM. Dunal and Moquin-Tandon recognised them, and considered them as the border of a five-lobed disc. But the nature of the disc is far from rigorously defined, and in many cases this term exactly applies to abortive whorls, as may be seen in

many Viniferæ, in the Myrsineæ, &c., families which are equally remarkable by the opposition of their stamens to the petals, to which they are equal in number. M. Duchartre mentions this example of the Myrsineæ as exhibiting exactly the symmetry of the Malvaceæ, with this difference, that a single stamen only corresponds to each petal. We do not agree with him in this opinion, but think that in the Myrsineæ there are two whorls of stamens independent of the corolla, the external or that alternating with the petal being metamorphosed or abortive. This appears to be demonstrated by the flowers of Theophrasta, or better still by Jacquinia. The author, arriving at the pistil of the Malvaceæ, finds in their different genera variations which are sufficiently considerable to establish four different categories, which he successively examines. In the first the quinary symmetry is at once apparent, and the five carpels differ but little in their mode of development from the views and theories generally adopted. In fact, we know that each carpel is considered as a leaf folded on itself, and that numerous organogenic observations exhibit this organ to us in the form of a minute scale which soon becomes concave internally, then tends more and more to close up by the approximation of the borders of the concavity, the adhesion of which completes the formation of the ovary, and forms a perfectly closed cavity, in which one or more ovules subsequently become developed. Now, imagine five of these scales or plates soldered together by their lateral surfaces, we then have the first condition of the pistil of Hibiscus. That will be a small border having five angles, which alternately project and recede internally; the projecting angles correspond to the borders of five carpels, approximated in pairs, and these angles projecting more and more, and converging, terminate by uniting, so as to form a quinquelocular ovary. But at a still earlier period, before the internal projections were marked, we had a pentagonal border which soon becomes festooned by five tubercles, the first indications of the styles.

In a secondary category, Malope, for instance, we also observe a pentagonal border, the five angles of which are opposite to the petals, and consequently correspond to the

place which five normal carpels should occupy. That border of the pentagon which is first united sends out a series of rounded tubercles, which subsequently become slightly swollen externally and inferiorly, so that each tubercle presents two enlargements; one external and inferior, the future ovary,—another superior and internal, the future style. The latter becomes elongated and raised in proportion as the former increases in size; but as it elongates, the stylous portions, remaining distinct at their summits, are confounded at their base,—at least all those which correspond to the same angle of the common support of the carpels; an angle which becomes more and more marked as far as the point at which the entire body is, as it were, cut into five oblique lobes loaded with ovules on every part of their surface. A bundle of styles, equal in number, distinct superiorly and united inferiorly, thus corresponds to each of these systems of ovaries; and each of these systems, in the general symmetry, plays an analogous part to that which we have found assigned to each of the bundles of stamens, because it occupies the place which a single carpel should occupy, and which it consequently represents. How is the cavity of the ovary formed?

M. Duchartre has not in this case found that the margins of a folded leaflet approximate towards one another, then touch and adhere; but, at a certain period, dissection has exhibited to him the cellular mass of the ovary excavated by a slight fissure, which continues to enlarge, without any manifest external appearance. A third category, and that includes the greater part of the Malvaceæ, exhibits the carpels not in constant relation with the quinary number of the other parts of the flower; but they form a perfect circle, are not grouped into five systems, and frequently their entire number is no multiple of five. However, M. Duchartre is led to believe that the same symmetry occurs here as in the preceding case. The ovaries and styles are developed in the same manner, with this difference, that all the styles are united inferiorly into a single cylinder.

Finally, a fourth category seems to belong to the first by the quinary number of the carpels; but here we observe ten

tubercles on the pistillary border, which subsequently form ten summits of distinct styles, and which correspond in pairs to five ovaries, the centre of which also becomes hollowed by a fissure, which forms its cavity without any change being externally apparent.

The necessary conclusion from all these observations is, that the parts, from their earliest appearance, present the relations of adhesion which they subsequently exhibit in the perfect flower. The monophyllous calyx on its first appearance was a body simple at the base. The petals coherent by their base with the staminal tube, originated from a base common to them with the stamens, and the latter at their origin were united by this base in the same manner as they appear subsequently. The ovaries were from the first grouped and adherent together, nearly in the same manner as the flower subsequently exhibits them, their styles being distinct at the summit, coherent in the rest of their extent, which has been more slowly developed. As regards the peculiar results to be deduced from these observations relative to the symmetry of the flower of the Malvaceæ, we have noticed them above, and it would be useless to repeat them. (*Annals of Natural History*, xvi.)

B. *The progressive development of the Papilionaceous Flower, among Leguminous Plants*, by Schleiden and Vogel:—

1. The flowers are at their origin perfectly regular.

2. The subsequently cohering parts originate as free points, are developed free, and cohere subsequently.

3. All the parts of the flower are at their first appearance green leaves.

4. Even in the earliest stage only one carpellary leaf is visible in the Leguminosæ, which is open in the direction of the axis.

5. The anthers are formed from leaves, the inner cellular tissue being converted in part into pollen; and the loculi originate at both sides of the margin of the leaf, which is subsequently changed into the bursting rima.

6. The ovules are formed alternately at the upper margin of the ovarium, and consist of the nucleus and generally of two integuments, rarely of an integumentum simplex.

7. The ovules of the Papilionaceæ are hemitropous.

8. The embryo originates from the pollen tube at the micropyle end of the embryonal sac, and increases either from this place towards the chalaza, or (being propelled by the pollen tube, which has become cellular, to the centre of the embryonal sac), both in the direction of the chalaza and that of the micropyle.

9. The epidermis of the seed is formed in the Leguminosæ only of one integument, which, however, always separates into several layers.

10. No endopleura tumida exists in the Leguminosæ; what has been considered as such is albumen, and, in fact, endosperm.

The authors have also discovered that the ovules of the genus Lupinus are only provided with a simple integument, while those of the other Leguminosæ always possess a double one. (*Annals of Natural History*, vol. iii.)

C. *Progressive development of Irregular Flowers*, by M. Barnéoud.—If a flower of Orchis galeata be examined in the very earliest condition, it will be found to consist of a simple cupula of very transparent tissue, on the border of which three round equal teeth soon become visible; these constitute the exterior verticil, which is formed exactly in the same manner as a true monophyllous calyx. In a short time a second cupula is seen to originate in the interior of the first, and its substance quickly becomes blended with that of the latter, except that its border exhibits three small prominences, perfectly equal and alternating with the teeth of the exterior verticil. Thus the author considers that organogeny clearly demonstrates in the Orchidaceæ, as in most other monocotyledonous families, analogies of the calyx and corolla of dicotyledons. The three nascent segments of the interior verticil of Orchis galeata are quite similar in the early condition, and it is not until a subsequent period that one becomes evidently broader and more fully developed than the two others; this it is which becomes the labellum. Orchis Morio, Ophrys araneifera, and two exotic genera, a Maxillaria and an Oncidium, presented exactly identical conditions.

In the Labiates, the corolla of Lamium garganicum when it first becomes visible, is represented by a little cupula scarcely hollowed out at all, bordered by five teeth which are very short, and at this time alone, quite equal, for two of them speedily cohere and become blended together to form a large, round, and very convex lamella, which subsequently becomes the helmet of the Lamium. Of the three remaining teeth, the central one also becomes much larger than the others, which are always small and atrophied. The evolution of the didynamous stamens exposes the singular fact, that the larger two originate rather before the other two, which they exceed in length at every period of their development. Among other Labiates, Ajuga reptans, Scutellaria Columnæ and commutata present us with the same phenomena. In Phlomis fruticosa the helmet is formed of two segments of the corolla, as in Lamium. In the Scrophulariaceæ the segments of the nascent corolla are also equal, but only at their origin. The inequality always manifests itself very soon, and earlier in proportion to the subsequent irregularity of the corolla (Antirrhinum majus, Linaria cymbalaria, Pentstemon Scouleri, Collinsia bicolor, Scrophularia verna). In the genera which possess a fifth, supplemental stamen, this is formed at the same time as the two smaller, and in the spot which remains vacant in the Labiates. The symmetry is then perfect. In the Birthworts (Aristolochia Clematitis and Pistolochia), the simple perigone composing the flower is, at its origin, a kind of tube, very short, at first with an equal and as it were truncated border; but this state persists but a very short time. One side of the mouth of the tube becomes much developed, so as to form the well-known limb of the Aristolochias, while the other undergoes but slight expansion.

In the Verbenes (Verbena urticæfolia), and in the Dipsaceæ (Scabiosa ucranica and atropurpurea), the irregular corolla follows the same law of development.

The petals of Leguminous plants are equal and alike at the origin of the flower; but a difference of form and size very soon becomes evident (Cytisus nigricans and Laburnum, Ulex europæus, Erythrina cristagalli). The case is the same in the

Milkworts (Polygala austriaca and chamæbuxus). From all these circumstances we may conclude that the irregularity of the corolla, at least in the families cited in this note, is a condition arising after the first appearance of the flower, and is a consequence of an inequality of development among the different parts which compose the floral envelope. (*Comptes rendus,* June 8, 1846. *Translated in the Annals of Natural History,* v. 18, by Mr. Henfrey.)

D. *Morphology of Confluent Flowers,* by the Rev. Mr. Hincks.—Two of these monstrosities occur in species of Iris, and much resemble each other. The species are I. versicolor, and I. sambucina. They have five parts in each circle, except that the inner circle of petals consists of four in one instance, and only three in the other. It is sufficiently manifest, that they are produced by the union of two flowers to form each, and they lead to the conclusion that, when Irises with four parts in each circle occur (which is not very uncommon), they are unions of two flowers, one-third part of each having perished in the junction. Various other monstrosities, consisting in the union of two flowers, are compared with the subjects of the description, particularly some of Œnothera, flowers having seven petals, fourteen stamens, and seven stigmas, where the parts preserved in the union are in exactly the same proportion as in the Irises.

A third specimen is described as a monstrous union of four flowers, in Scrophularia nodosa. The flower-stalk might be perceived to be formed by the adherence of several stalks. The parts found were fifteen sepals, sixteen petals, twenty stamens, and separate ovaria, each with two carpels, and a third ovarium formed by the adherence of two more, and consisting of eight carpels. Mr. Hincks is of opinion that the union of four flowers would account for these numbers of parts. The increased development of the circle of stamens, five appearing for each flower, though of these several are united in threes together, and two are imperfect, and the increased number of carpels in two of the united flowers, he regards as interesting facts. He thinks that they show that the union of the flowers had the effect of diminishing

and rendering more equable the pressure on the interior circles, so as to allow of the growth of parts which are usually abortive. (*Annals of Natural History*, vol. iv.)

E. *Change of Sex under the influence of external causes.*—Mr. Knight long ago showed that a high temperature favoured the development of male flowers, and a low one that of females.

In a forcing-house, a fire of sufficient power only to preserve in the house a temperature of about 70°, during summer, was employed, but no air was ever given, nor its escape facilitated, till the thermometer, perfectly shaded, indicated a temperature of 95°; and then only two of the upper lights, one at each end, were let down about four inches. The heat of the house was consequently sometimes raised to 110°, during the middle of warm and bright days, and it generally varied, in such days, from 90° to 105°, declining during the evening to about 80°, and to 70° in the night. Late in the evening of every bright and hot day, the plants were copiously sprinkled with water, nearly of the temperature of the external air; and the following were the effects produced upon the different species:—

A plant of the Water Melon grew with health and luxuriance, and afforded a most abundant blossom; but all its flowers were male. On the other hand, Mr. Knight had many years previously succeeded, by long-continued very low temperature, in making Cucumber plants produce female flowers only; and he entertained little doubt that the same fruit-stalks might be made to support either male or female flowers, in obedience to external causes. In like manner, when Strawberry plants are subjected to a high temperature in forcing-houses, they produce male flowers; and females only in a comparatively low one.

It would seem, however, that other external causes, beyond mere heat, influence the production of males or females. In the Ray Reports it is mentioned that M. Hampe observed, in a bush of Salix repens, that twigs above the water blossomed as females, whilst those twigs which had been in the water, and subsequently blossomed, when the water was dried up

had only male blossoms. He endeavoured to prove, by other instances, that Diclinous plants, situated in wet localities, produce more male than female blossoms. (See *Linnæa*, vol. xiv. p. 367).

These facts conclusively establish the important point, that the male and female organs have a common origin, and become one or the other in the course of development, according to the influences to which they are exposed.

CHAPTER III.

OF THE COMPOUND ORGANS IN FLOWERLESS PLANTS.

General Considerations.

In the foregoing pages an attempt has been made to elucidate the true nature of the different organs which exist in the most perfectly formed plants; that is to say, in those whose reproduction is provided for by the complicated apparatus of stamens and pistils. We have now to examine the analogies, if any, of those lower tribes, some of which are scarcely distinguishable from animals, where there is no evident trace of sexes, in which nothing constructed like the embryo is to be detected, and which seem to have no other provision made, in many cases, for the perpetuation of their races than a dissolution of their cellular system.

Although the general facts belonging to this subject will be found in the *Vegetable Kingdom*, yet there are some circumstances not alluded to in that work, and others which require an extended explanation, which can be best introduced into this place as being of a supplementary and explanatory nature.

If the highest forms of flowerless plants are selected for examination, they will be found to correspond very nearly with many groups of Endogens; as, for example, when Clubmosses (Lycopodiaceæ) are compared with Conifers, and Ferns with Palms. And so, in like manner, if the lowest forms of flowering plants are compared with flowerless species —Lemnads with Crystalworts (Ricciaceæ), or Podostemads with Liverworts—there will still be a great resemblance between them. But among flowerless plants there is a far lower form of structure, with which flowering plants have nothing comparable, where species are reduced to mere threads, as in Confervas, or small clusters of cells, as in

Brittleworts (Diatomæceæ), or simple cells, as in some of the genera constituting Blights among Coniomycetous Fungals. And even in these instances where flowering and flowerless plants resemble each other, the similarity is confined to the organs of vegetation, no resemblance being usually discoverable, except by the aid of forced analogy, between the reproductive organs of the two great forms of plants. It would seem, indeed, as if the mode of producing reproductive organs was wholly changed among flowerless plants, and that such resemblances as sometimes appear to remain, are but the result of general tendencies which, perhaps, are never lost in any part of the kingdom of plants. It is, therefore, mainly to the peculiarity of the reproductive organs that the following remarks will have relation.

There are two main questions which require to be considered independently of the special circumstances that vary from one natural order to another. They are: 1. *Have flowerless plants sexes?* 2. *Have they seeds?*

The question of SEXES has long divided the botanical world. There are some who, like Linnæus, assume sexuality to be indispensable, and who therefore find traces of it every where. There are others who, perceiving no necessity of the kind, demand proof of the so called sexes being so, and refuse to acknowledge sexes in the absence of the same proof as is required among flowering plants. The first are sometimes satisfied with assuming the existence of a male and female principle even in the cells of Confervæ, where nothing visible exists; the second are of opinion, that what can neither be seen, nor detected otherwise, cannot be said to have existence. The former opinion is maintained, with his usual acuteness, by Mr. Thwaites, as will be seen hereafter under Mosses and Brittleworts. And the point may be conceded in the view which he takes of sexuality: for it is not so much the mere presence of sexes, or of a mysterious sexual essence, that is denied, as that the organs called sexual in flowerless plants, are of the same, or a similar, nature as those known to be sexes in the higher orders.

The late Mr. Griffith may be regarded as the most experienced modern botanist who has supported the sexuality of flowerless plants; and, therefore, in justice to so great an observer, I cannot do less than quote his words from an excellent paper in the Nineteenth Volume of the *Linnæan Transactions.*

"The question of the sexuality of Acotyledonous plants is so intimately connected with the subject of vegetable embryology, that I trust I shall be pardoned for hazarding a few observations derived from personal experience.

The more developed Acotyledonous plants, which I take to be Filices, Lycopodineæ, Isoetes, Marsilea, Salvinia, Azolla, Hepaticæ, and Musci, appear to me to present two very distinct types of organisation, at least, as regards the female organ. In one type there is an evident pistillum containing an ovulum, and this appears to be generally connected with limited development of the organs of vegetation. In the other there *is no evident pistillum, nor any palpable point* on which analogy would indicate that the male influence would be exerted. That type is also remarkable for the development of the organs of vegetation.

In Musci, the evidence of the mutual action of the sexes, appears to me very satisfactory; the *usual discoloration* of the stigma and canal of the style is distinctly observable, and is followed by changes, *confined, however, to change of situation,* affecting the cell pre-existing in the cavity of the ovarium, and which is analogous to a Phænogamous ovulum. In Hepaticæ, particularly the vaginulate species, the circumstances would appear to be the same; and in the evaginulate ones, and, perhaps, also in Riccia, still nearer *approaches* are made by the changes which the pre-existing cell undergoes *to the ovulum* of Phænogamous plants.

In the Azolla I have examined, which is the only other plant which appears to me pistilligerous, (he had at that time no knowledge of the development of Salvinia), the pistilla in each involucre are two, and both present the appearance so generally characteristic of fertilisation. *The changes subsequent to this are, however, very different,* giving rise in one pistillum to the supposed male, in the other to a series of sporules derived from the characteristic dividing process.

On Lycopodineæ *I have no observations*, and on Filices merely a few *surmises* to offer. I *believe* that every species will be found to present a male apparatus, which, I think, was first pointed out by the great Hedwig, and subsequently by M. Link. I have lately alluded to it without having any previous knowledge of the labours of the two above-mentioned botanists. The fertilisation of Ferns I *believe* to be interpreted by Anthoceros, provided my observations on that genus be found to be correct. The *only difficulty exists in the anthers* not appearing, in some cases at least, to dehisce; but I beseech botanists not to cast away the opinion of the very important nature of these bodies on a solitary objection; they will remember that until very lately an absorptive process was generally adopted to explain the fecundation of Asclepiadeæ and Orchideæ, and even adhered to, when a beautiful train of reasoning and observation had reconciled them, in all the essential points, to the ordinary plan.

With regard to Marsilea, I have to remark that the observations of M. Fabre, as given by M. Dunal (*Ann. Sc. Nat., N.S.*, t. vii. p. 221), scarcely agree in one particular with some observations on a Marsilea, I believe M. quadrifolia, made by myself at Bamo, on the Irrawaddi, in 1837. In the species I then examined I found the organs to be of two distinct kinds attached to the veins of the involucre. Of these two kinds, one only is subsequently subjected to the usual ternary or quaternary division, from which result bodies altogether similar to the acknowledged *spore* of other Acotyledonous families. The other body has no analogy, in my opinion, to the acotyledonous form of anther. In M. Fabrei, however, the females have been represented as having curious analogical resemblances to the Phænogamic pistillum; and what is, perhaps, more extraordinary, the anthers are said to be simple sacs, containing granules and molecules, and apparently are similar to the pollen of certain Naïades, Balanophoreæ, Rafflesiaceæ, &c.

In Isoetes the *males of authors* are nothing but *modifications of the spore;* and in I. capsularis, Roxb., they seem to be merely *temporary* modifications: they have, in fact, so precisely a common development that it is scarcely allowable to

allot to them the performance of such opposite functions as those usually attributed to them.

The true male may, *perhaps,* be found in the cordiform, fleshy lamina above the receptacle of the spores, from which it is separated by a lamina, perhaps analogous to the indusium.

The transition between the two types exists in Anthoceros, which, in the development of its anthers and in habit, has much in common with the pistilligerous type. In this genus the male *influence is first exerted on the surface of the frond,* and thence is extended through the upper parenchyma to that part of the substance of the frond from which the reproductive organ is to originate. *So far as I know, nothing like a pistillum appears to exist:* and though there is a calyptra, it has nothing, except situation, in common with the calyptra of Musci and Hepaticæ, being only that portion of the parenchyma between the surface of the frond and the spot whence the young reproductive organ has originated.

I take it to be a valuable example, inasmuch as it shows, if my explanation be correct, that the male *may* not only *act successfully without a pistillum,* or any similar co-existing body, but that it may act mediately. Consequently, Ferns are easily, and I think fairly, explainable, *provided the glandular hairs are allowed to be the males.* And in what do they differ from the anthers of certain Musci and Hepaticæ, or from the anthers of Phænogamous plants, when they are cellular, undivided bodies containing grumous molecular matter? In regard to points like these, most botanists have, like some zoologists, pitched upon one standard of organisation, and that at the wrong end of the scale. But those who look for a smaller degree of complication in low organisations, or for a greater degree of reduction to the elementary substances, will, I think, not only admit that the anthers of all the above families, so far as they have been well observed, have a marked correspondence with, but that they are also analogous to, very young anthers of Phanerogamous plants. I might ask what they have in common with gemma? Is the structure of a gemma compatible with a cellular sac containing a grumous matter? Is the function of a gemma more compatible with such a sac, often inclosed in a cavity in the

frond, from which it does not escape, and in which they are, functi officiis, to be found in the shape of withered empty sacs?"

In the *Calcutta Journal*, the same author repeats these opinions in a more concise way. "It appears to me," he says, "sufficiently plain, that in the higher Acotyledonous plants, in which I include Filices, Lycopodineæ, Isoeteæ, Equiseteæ, Marsileaceæ, Salvinidæ, Musci, Hepaticæ, Characeæ, there are at least two modifications of the female organ representing the modifications of the same organ of Cotyledonous plants.

The term Pistillum has been applied to the female organ of Mosses by some first-rate botanists, though not without violent opposition from some systematists. Since the examination of Balanophora, its application is, if possible, still more legitimate. In my opinion it is not to be doubted, that not only have Musci and Hepaticæ a pistillum, but that this contains an ovulum.

The analogies presented by the plants which form the subject of this communication, to those Cotyledonous plants in which the ovulum is entirely naked, either, as is supposed to be the case in some, without a carpel leaf, or with that organ in an expanded not a convolute state, are, I think, equally striking.

It may be worthy also of remark, that in proportion as Acotyledonous plants become, *so to speak*, less pistilligerous, their vegetative organs appear to be more developed. This is evident if a Fern be compared with a Moss. And it seems to be so closely followed up, that Salvinia which has less, perhaps, of the atropous phænogamous ovulum than Azolla, has its organs of vegetation considerably more developed."

If the reader will turn to the words which are here printed in Italics, he will at once perceive upon what inconclusive arguments these opinions are founded. Not the slightest proof is adduced *from experiment* that the parts called male and female exercise the function of the sexes. No attempt is made, for none could be made, to show that they are analogous to the undoubted sexes of Flowering plants, because of their being analogous in structure; but the whole argument

is made to turn on if, or perhaps, or trifling coincidences. It is to be remarked, too, that an appearance of speciousness is given to doubtful arguments by the employment of the terms style, stigma, pistillum, ovarium, ovule, and anther, as if such organs really existed; the fact being, that the use of the terms is wholly arbitrary, and that its fitness is the first point to establish. It is, moreover, curious to observe upon what false ground this admirable observer, but bad reasoner, stands when he is obliged to assume the existence of some incomprehensible power of intus-susception, for no better reason, as it would seem, than that it has been *proved not to exist* in Flowering plants.

Without pretending to defend those who have supposed the antherids of Flowerless plants to be gemmæ, that is, buds, I may also remark, that the supposition involves no such absurdity as Mr. Griffith supposed; because the essence of a bud is its cells; because all cells are capable of forming buds; and, therefore, because as all antherids consist of cells, they too may possibly form buds.

That Flowering plants have no seeds, properly so called, that is to say, no propagating bodies, formed as a consequence of the contact of sexes, is certain, if the foregoing arguments have any force. The actual condition of the reproductive bodies, or spores, of flowerless plants confirms the opinion; for with most botanists it is not now a question of whether spores are seeds, but whether spores are not of the same nature as pollen. "The identity of the spores of Acotyledons," said Mr. Griffith, "and the pollen of Cotyledonous plants is, perhaps, strengthened by the curious resemblance of the fructification of Equisetum to the male apparatus of Cycads; in which also the pistillary apparatus, in this view to be looked on as a sort of nidus, is of great simplicity." This opinion seems to have originated with Mr. Valentine in 1833, as will be fully shown hereafter in speaking of Mosses. Without for a moment expressing an opinion favourable to such a supposition, which I believe to be quite unfounded, I only refer to it for the sake of showing how entirely different spores must be from seeds to have given rise to such a

speculation; for what botanist would think of pronouncing *true* seeds to be pollen grains?

Even Mr. Griffith, in attempting to show an analogy between spores and seeds, does not pretend to make out any identity between them; and his whole account is that of a growing point,—a focus of vitality,—and not a seed.

One cannot but wonder that so clever a man should not have perceived how entirely the following criticism upon his brother botanists applied to himself.

"The terms used in most of the characters are in several instances unintelligible, as *generally is the case when a name is made to pass for an explanation*, or when the application of a name is founded on mistaken ideas of the nature or analogies of certain parts. In the late work on Genera by M. Endlicher, I find the terms indusium, calyptra, and columella, all in use. And in a note, other general analogies are so extended as to refer one of the organs to the type of a 'flos monadelphus ovario infero.' Now of the terms above cited, there appears to me only one (calyptra,) capable of legitimate application, but only as far as regards mechanical function. The difference otherwise is very great; for in Azolla the calyptra is nothing more than what is presented by every dehiscentia circumscissa of a fruit, and is limited to one only of the capsules; while in Mosses and all calyptrate Hepaticæ, it is the pistillum displaced from its base at a remarkably early period. A more real analogy of this part in Azolla is to be found, perhaps, in the seed of Lemnaceæ during germination. The term indusium is applied to the capsule itself, whereas, correctly speaking, it is only applicable to a covering of capsules, of a partial or general nature, derived from the surface of the foliaceous body or frond, on which the capsules are situated. This term indusium, which should be distinguished from involucrum, is at most only applicable to Azolla. A columella is the remains of an originally continuous, solid, cellular tissue, unaffected during the development of the spores; it is a continuation either of a partial or a special axis. It may, I believe, be justly considered analogous to the connectivum of a bilocular anther, or the cellular tissue between the cavities of a plurilocular anther. In Azolla it

does not appear to be even solid. It may be seen, also, that the same character gives an indusium to one, a calyptra to the other body, while the application of the term calyptra ceases to be even mechanically correct from being applied to the whole capsule." "In the sporula, so called," he says, "of the more developed Acotyledonous plants, we have organs consisting of two envelopes; the inner of which contains granular matter, has remarkable powers of growth, and, so far as function is concerned, appears to be alone essential. The proper stimulus calls this membrane into growth, and from the apex of its extension cells are developed; from these others again are produced; and from the centre of the mass thus formed, originates at a certain period the growth of the true axis. Similar phenomena take place in the formation of the seed of Phænogamous plants, with this difference, that the albumen, unlike, perhaps, the thallus of the Acotyledonous plant, is not a direct growth from the pollen tube. Such other differences as appear to exist are of minor importance; they consist in the different nature of the stimulus calling forth the extension of the inner membrane, in the condensation of the growth forming the seed, which may be reasonably inferred to arise from the confined situation in which they occur, and in the cells composing them containing fecula, not green globules, also apparently a consequence of the confinement alluded to. The functions of the intermediate growths are in both precisely the same, viz., that of nourishing the young axis until it is sufficiently matured to enable it to maintain an independent existence.

"The germination of such Acotyledonous plants appears, therefore, to me to be analogous to the development of the seed of Cotyledonous plants, and the perfect state of the lower is analogous to the imperfect state of the higher organisation. And to a similar observance of the phases of development I am tempted to attribute the prevalence of albumen in Monocotyledonous plants, although this is apparently strongly contradicted by the occurrence of the most exalbuminous and perfect Monocotyledonous embryos in the least organised plants of the class; and, perhaps, equally so by its prevalence in the monopetalous division of Dicotyledons.

"The analogy between the spore and the grain of pollen has long been remarked; and its extended application to the processes, constituting germination in the one instance, and the formation of the seed in the other, was given by Mr. Valentine in 1833. I think I am correct in naming it analogy rather than affinity, from considerations derived both from development and functional powers. For the spore of these particular or more developed Acotyledons is not produced by a comparatively simple process as the pollen of Cotyledonous plants is, but is the result of a process as complicated, if not more so, than the development of the seed, and, in addition, presents in its first stages very curious similarities with the development of a true ovulum. Both agree in being set in action by the agency of a comparatively simple structure; but the early complication of the process in the higher Acotyledonous plants would at once lead me to suspect that the organs alluded to *are not strictly similar;* for the earlier we proceed in our investigations, the more marked should be the resemblance, and the more simple both structure and function. The powers of growth in the two are remarkably contrasted, and will be still more so, if the albumen be ultimately found to be derived from the female. M. Schleiden, on the contrary, is of opinion, that between the spore and the embryo there is an affinity amounting to fundamental unity; and Mr. Valentine not only holds the same opinion, but, overlooking the obvious difficulties to which M. Schleiden has adverted as presented by some of the higher Cryptogamic families, denies to these plants entirely a provision similar to that of the pistillum of Phanerogams." (*Linn. Trans.*, vol. xix.)

How little analogy there really is between the spores of some flowerless plants and the seeds of the higher orders is sufficiently shown by the following excellent account of the formation of that of Vesiculifera concatenata, an Algal, by Mr. Thwaites:—

"This plant occurs in ponds on a common near Bristol, and is of a pleasant pale apple-green colour. The cells are usually from five to seven times as long as broad, and are lined with but a small quantity of endochrome, which is

disposed in a reticulate manner. Some of the cells, however, may be observed to be slightly inflated, and to contain a larger amount of endochrome than the rest: in each of these inflated cells a spore is subsequently formed, and in the following way:—The endochrome, after attaining a certain degree of density from an increase in its development, not from any derived from a contiguous cell, moves towards one end of its cell; it (the endochrome) shortly becomes divided into two very unequal portions, the larger and terminal one of which becomes converted into the spore, and the smaller portion is found to be separated from this by a single septum. A process has, in reality, taken place analogous to the fissiparous division of the cell of Zygnema; two cells have been formed within the original one, but in the Vesiculifera one of these new cells is the spore. This is a fact of considerable physiological importance."

The same observer found that in Vesiculifera æqualis, the process of the formation of the spore is similar. In that species, however, he was able to trace the mode of development of the two or three contiguous spores, which are sometimes to be seen in the filaments of this species. The first spore is formed in the way he previously mentioned, and arrives at considerable maturity before there is any appearance of one, contiguous to it, being produced; but it may then be seen that the smaller portion of endochrome, which had been separated just previously to the first spore being formed, and which then occupied but little space in the cell, has become considerably increased in amount, an increase having also taken place in the length of the cell; at length the process of division, &c., occurs as before, and a second spore is formed adjoining the first. The formation of a third spore involves a similar chain of phenomena.

The spores of flowerless plants are usually regarded as differing from seeds in not germinating from any fixed point, but from whatever part is exposed to moisture and darkness. This, however, is denied by Mr. Valentine in the case of Pilularia, "for it is quite certain in that instance that germination invariably takes place at a fixed spot, which may be pointed out before germination has commenced. It is at

that part of the sporule indicated by the three radiating lines which appear to have been produced by the pressure of the three other sporules that originally helped to constitute the quaternary union; and as the spores of all the other tribes appear, according to Mohl, to be developed in similar unions, it is most probable that similar lines indicating a valvular dehiscence also exist on them. This is certainly the case in some Mosses, for instance, in Œdipodium, and in Isoëtes, Lycopodium, and Osmunda regalis; and in those instances where such a structure is not visible, it is probably owing to a thickening of the membrane, or a deposition of opaque matter on its surface, as in Pilularia." (*Linnæan Transactions*, xviii.)

But it is time to proceed to particulars.

1. The Filical Alliance.*

(*Ferns, Danæads, Adders Tongues.*)

Ferns are plants consisting of a number of leaves, or *fronds* as they used to be called, attached to a stem which is either subterraneous or lengthened above the ground, sometimes rising like a trunk to a considerable height. Some of them are the largest of known vegetables in which no organs of fructification analogous to those of phænogamous plants have been discovered. Their stems often acquire the height of as much as fifty or sixty feet, or even more, and in that case are usually unbranched, of the same thickness at the upper and lower ends, and grow exclusively at the point. The surface of the stem is often hairy or shaggy, sometimes spiny, and in all cases is more or less copiously furnished with callous points, which render it rough like shagreen leather, or covered with roots, sometimes entangled into a compact layer much thicker than the trunk itself, and appearing to be the extension of the callous points.

The anatomy of tree ferns has been skilfully elucidated by Mohl, to whose treatise upon the subject (*Martius, Plant. Crypt. Bras.* p. 40.) the reader is referred for the details of their curious organisation. I must content myself with a

* See "Vegetable Kingdom," p. 74.

very general statement. The trunk is covered with a hard rind, occupying the place of bark, two or three lines thick, and consisting of hard brown parenchymatous and prosenchymatous tissue, the latter, if present, being on the inside. Within the rind is a mass of parenchymatous thinner-sided tissue, which is analogous to the horizontal cellular system of exogens and endogens. The wood is formed by concave or sinuous plates, whose section has a lunate or wavy form, and which are closely arranged in a circle next to the rind, enclosing a column of parenchyma, just as the wedges of wood in exogens enclose a similar column of pith; and in like manner there are openings between the plates, through which the subcortical and medullary parenchymas communicate. Each plate consists externally of several layers of hard brown prosenchyma, next within which is a pale stratum of thin-sided parenchyma, and in the centre of all is a soft pale mass of trachenchyma, consisting of large scalariform and spiral vessels (sometimes $\frac{1}{20}$ line in diameter) mixed with soft parenchyma. Externally the stem is marked with long, or rhomboidal scars, the surface of which is broken into numerous hard ragged projections which represent the broken communication between the trunk and the leaves, by the fall of which the scars are produced. Next the apex of a trunk the scars are always arranged with great regularity, but towards the lower part of the stem they become much longer, irregular in form, and are separated by deep furrows; from which it is to be inferred, that, although in these plants no new parts are added, except at the point of the trunk, yet that the parts after being formed do grow both in length and breadth.

Below the scars of the leaves are often (always?) found elliptical or roundish perforations, filled with a powdery matter. These have no obvious analogy in other plants, unless they are to be compared to the perforations in the rhizome of Nymphæa, which, however, according to Trecul, are caused in that plant, by the falling away of roots. (See last volume.)

Their petioles, or *stipes* (*rachis* W.; *peridroma*, Necker), consists of sinuous strata of indurated, very compact tissue,

connected by cellular matter; and the wood of those which have arborescent trunks is formed by the cohesion of the basis of such petioles round a hollow or solid cellular axis. The organs of reproduction are produced from the back or under side of the leaves. In Polypodiaceæ, or what are more commonly called dorsiferous ferns, they originate, either upon the epidermis or from beneath it, in the form of spots, at the junctions, margins, or extremities of the veins. As they increase in growth they assume the appearance of small heaps of granules, which heaps are called *sori*. If examined beneath the microscope, these granules, commonly called *sporangia, thecæ, capsules,* or *conceptacles,* are found to be little, brittle, compressed bags formed of cellular membrane, partially surrounded by a thickened longitudinal ring (*gyrus, annulus, gyroma*), which sometimes at the vertex loses itself in the cellularity of the membrane, and at the base tapers into a little stalk. The sporangia burst with elasticity by aid of their ring, and emit minute particles named *spores* or *sporules,* from which new plants are produced: as from seeds, in vegetables of a higher order. Interspersed with the sporangia are often intermixed articulated hairs; and, in those genera in which the sporangia originate beneath the epidermis, the sori, when mature, continue covered with the superincumbent portion of the epidermis, which is then called the *indusium* or *involucrum* (*membranula,* Necker; *glandulæ squamosæ,* Guettard), In Trichomanes and Hymenophyllum, the sporangia are seated within the dilated cup-like extremities of the lobes of the frond, and are attached to the vein which passes through their axis, which is then called their *receptacle.* In Gleicheniaceæ, the sporangia have a transverse complete, instead of a vertical incomplete, ring, and they are nearly destitute of stalks; in others the sori occupy the whole of the under surface of the leaf, which becomes contracted, and wholly alters its appearance: the sporangia have no ring, and the cellular tissue of their membrane is not reticulated, but radiates regularly from the apex.

In these plants it has been in vain endeavoured to prove the existence of organs of fecundation. Nevertheless, as it was difficult for sexualists to believe that plants of so large a size

were destitute of such organs, it has been considered indispensable that they should be found; and, accordingly, while all seem to agree in considering the sporangia as female organs, a variety of other parts have been dignified by the title of male organs: thus, Micheli and Hedwig found the latter in certain stipitate glands of the leaf; Stæhelin, Hill, and Schmidel, in the elastic ring; Kœleruter, in the indusium; Gleichen, in the stomates; and Von Martius, in certain membranes enclosing the spiral vessels.

Blume, Sprengel, Presl, and especially Link, imagine the anthers of ferns to be long clavate threads, separated by septa into articulations, generally simple, rarely ramified; the last articulation being thicker, and filled with a delicate granular mass. This mass is said to be at times exuded at the last articulation, when it surrounds it as a crust. Such threads are frequently longer than the sporangia, and are easily distinguished from the latter when young. Some botanists think it probable that these may really be the stamens of ferns. Link, who says he has found them, after frequent search, in most of the ferns which he subjected to microscopical examination, has published some beautiful drawings of them. There is not, however, at present, the slightest evidence to show that they possess any male properties.

The late Colonel Bory de St. Vincent contended that impregnation may take place in plants without the agency of pollen, and he affirmed that hybrid ferns exist; which, if true, would render it impossible to deny the existence, in this large order, of sexual organs; and, in that case, the threads described by Link might be *supposed* to perform the office of stamens; but the latter botanist has not availed himself of the supposed fact of hybrid ferns being producible. On the contrary, in the following observations he entirely disbelieves that statement, as I do:—

"The remarkable phenomenon which M. Martens first observed at Löwen, in the botanical garden, that an intermediate species of fern grew where Gymnogramma calomelanos and chrysophylla were situated, has also been observed by Bernhardi in Erfurt (Ottos and Dietrichs Flora, 1840, pp. 249, and 325). A fern has grown in the botanical garden of

that place, which holds a middle rank between Gymnogramma distans and chrysophylla, species which are cultivated in the same garden, and had been frequently standing next each other. The frond of this intermediate fern is doubly pinnate, decreasing towards the upper part; the shape of the pinnæ and pinnate divisions holds a middle rank between the shape of these parts in its progenitors. The white powder of G. distans is scattered about at the base of the fronds and the pinnæ, where they are attached to the footstalk, and the yellow powder of G. chrysophylla, but rather paler, is seen on other parts. M. Bernhardi considers these forms as real hybrids; he recommends particular attention to the fructification of the fern in these species of Gymnogramma; he thinks that if his assertion respecting the male fructifying parts of these plants should be confirmed, the phenomenon may be more readily explained, than if other parts are regarded as anthers. M. B. rejects the opinion too hastily, that the species of ferns, of which such intermediate forms have been observed, may be modifications of the same species; indeed, these species are very similar, and ferns are by no means so constant in their forms as the author thinks; on the contrary, they change very frequently, and much more so than other plants. It is often the case, that we see long and short, pointed and blunt pinnæ, on one and the same frond of the larger Polypodiaceæ." He, therefore, rejects the idea of imaginary hybrids proving that ferns have sexes; and, with regard to his own supposed anthers, he observes, that, "If any parts are to be regarded as anthers, they evidently are those which Blume first of all definitely indicated, and which are represented in the same part of the *Icon. Select. Anatomicæ Botanicæ*, tab. 3, fig. 1—5; they certainly have the greatest analogy with anthers, *although I by no means attribute to them the same functions as are possessed by the anthers of* phanerogamous plants. For we need only reflect upon the eye of the mole, which certainly cannot see with it, to be convinced that nature sometimes also arranges things for no particular purpose. Provided even that these anthers of the fern, or the parts assumed to be such by Bernhardi, really possessed the function of impregnation, I yet cannot see how

hybrids can be produced in this class of plants. With regard to the anthers of Blume, they are too near the pistils of the same species; and as to those of Bernhardi, the pistils in other species are situated at so remote a locality, that it is impossible to explain how the one could get to the other." (*Ray Reports.*)

"The germination of ferns is simple: the shell of the spore bursts regularly or irregularly, and out of it the kernel extends in the form of a foliaceous expansion, which subsequently forms a bud, whence the plant proceeds under the form which is proper to its nature. This mode of germination possesses some similarity to that of Monocotyledons; but here the evolution of the kernel is a mere state of rapid transition." (*Link.*)

In ADDERS TONGUES (Ophioglossaceæ), a remarkable race of Ferns, the fertile leaf is rolled up in two lines parallel with its axis or midrib, and at maturity opens regularly by transverse valves along its whole length, emitting a fine powder, which, when magnified, is found to consist of particles of the same nature as the spores found in the sporangia of other ferns; here there are no sporangia, the metamorphosed leaf probably performing their functions. Such is my view of the structure of Adders Tongues; but by other botanists it is described as a dense spike of two-valved capsules, dehiscing transversely.

2. THE LYCOPODAL ALLIANCE.*

(*Clubmosses, Pepperworts.*)

CLUBMOSSES (Lycopodiaceæ) are leafy plants with the habit of gigantic mosses. Their leaves and stem have the same structure as those plants, except that the former are sometimes provided with stomates, and the latter with a central bundle of vessels. Their organs of reproduction are kidney-shaped two-valved cases, usually called *thecæ, sporocarpia, conceptacles,* or *capsules,* either, 1. filled with minute powder-like granules, which, in consequence of lateral compression,

* See "Vegetable Kingdom," p. 68.

from being spherical, acquire the figure of irregular polygons; these are the *Antheridia* of modern writers; or, 2. containing three or four roundish fleshy bodies, marked at the apex by a three-legged line, and each of which is at least fifty times larger than the granules contained in the first kind of theca; the latter are also named *oophoridia*, and are said by Brotero to burst with elasticity. The first kind of theca is found in all species of Lycopodiaceæ; the second is only found in a few. The contents of both are believed to be sporules; but no satisfactory explanation has yet been offered of the cause of their difference in size, and probably also in structure. I would suggest that the powder-like grains are true sporules, and that the large ones are buds or viviparous organs, as has already been stated by Haller and Willdenow. A writer in the *Transactions of the Linnæan Society* has figured and described the growth of the larger grains of Lycopodium denticulatum, and he considers that they exhibit the germination of a dicotyledonous plant; but, independently of any mistrust which may attach to the account, it is obvious enough that his own drawings and description represent a mode of germination analogous, not to that of dicotyledons, but rather to that of monocotyledons, and also reducible to the laws which govern the incipient vegetation of a bud.

The powder-like sporules are inflammable, and have been supposed by Haller, Linnæus, and others, to be pollen, while the larger have been considered seeds; and to a part of the surface of the theca the office of stigma has been attributed. The thecæ themselves have been fancied to be male apparatus by Kœlreuter and Gærtner.

Both kinds of theca, the oophoridium, and antheridium, have been critically examined by Karl Muller, whose observations are the latest upon the subject.

"The oophoridium," says this author, "is the whole metamorphosed terminal bud of a main axis. It is therefore an axial organ."

This opinion is supported upon the following grounds:—The position of the oophoridium is opposite the spike in the early condition, and hence he regards the oophoridium and spike as two metamorphosed branches into which a main

branch has just divided. It is only at a later period that both oophoridium and spike appear to belong to the same axis. K. Muller thinks that there can be so little doubt about our having, in this case, to do with two branches, that, in the absence of other argument, this mode of development alone would justify his opinion. All that is requisite to form a branch occurs in the oophoridium; it is covered by two leaves, and they are to be regarded as the two first of what otherwise becomes an oophoridium. He finds, moreover, that near the oophoridium and the spike is often produced the same root which appears in the bifurcation of a main axis; that in L. denticulatum, &c., only one oophoridium is found on each fruit-bearing axis, which stands in direct connection with the scattered fructification of the said axis. The branches of L. denticulatum divide, he thinks, too frequently for the branch to produce many oophoridia. It is too thin to form a main axis out of which oophoridia might be developed. It is different with L. selaginoides. "Here the axis of the fruit is very thick, and thus it is suited to form branches which may develope into oophoridia. Another proof is, that in the young condition the oophoridia are all compressed, as the branch of L. denticulatum always is, since the oophoridium is, in fact, only the transformed apex of the branch." The internal direction of the vascular bundle belonging to the oophoridium is a still better evidence, for it runs into its pedicel. In short, Karl Muller regards it as a modification of the growing point, an hypothesis which he thinks is rendered incontrovertible by an anomaly which he once observed where both branches of the fruit-bearing axis had been transformed into oophoridia. "Here, of course, the spikelet was wanting, and two oophoridia were opposed to each other, the most complete proof that the terminal bud of that branch had been transformed into an oophoridium, which properly should have produced a branch." "Consequently," he adds, "the view of H. Mohl and Schleiden in reference to the oophoridium, that this sporangium is a production from the leaf, is certainly incorrect; neither is it formed of carpellary leaves, as Bischoff endeavoured to show."

The next question is, the import of the antheridium? This

much he thinks certain, "that the antheridium can be no product from a leaf, since it is formed from the axis contemporaneously with the leaf. As little can we regard it, with Bischoff, as formed by the growing together of leaves. Besides, Mohl has already triumphantly refuted this view. But that we have to do with a metamorphosed bud, on the contrary, cannot be disputed; since the first, rounded antheridium-spherule possesses all the peculiarities of a bud, epidermis and a formative cell-contents. The only question is, whether we are to regard this bud as analogous to those so often met with in the axils of the leaves." He considers it a lateral bud (the bud of a twig), which is only distinguished from the terminal bud of the branch developed into the oophoridium by the circumstance that the latter is a principal branch, which possibly was capable of a more extensive development into branch and foliaceous organs, while the twig which is developed into an antheridium is but a small particle of such a main branch. "That it is a twig, appears to me to be shown by the internal structure of the fruit-axis, since from its central vascular bundle are given off real lateral branches to each bud (antheridia). Yet it must be freely admitted, that the vascular bundle does not actually run into the peduncle of the antheridium, but terminates before reaching it, and it is merely elongated cellular tissue which proceeds from the vascular bundle into the peduncle." (See the whole paper illustrated with figures in the *Annals of Natural History,* vol. xix.)

Pepperworts (Marsileaceæ) consist of plants differing so much from each other that the genera require to be examined separately.

Of Marsilea the most complete account has been given by M. Fabre. In Marsilea Fabri the fructification consists of a two-valved coriaceous involucre (*sporocarpium,* Endl.), having its valves held together by a central line continuous with the stalk: this involucre seems to be a modified leaf. From the stalk there rises a mucilaginous ring to which adhere minute ramifications of the spike, terminating in oblong spikes covered with fructification. After a time the mucilaginous

ring detaches itself from the stalk at one end, straightens, and carries up with it the spikes of fructification, whose connection with the stalk is then destroyed. The spikes are at first enveloped in a mucous membrane, and are composed of two sorts of bodies closely packed together, and considered by M. Dunal to be ovules and anthers. These bodies are sometimes intermixed, sometimes stationed separately from each other. The so called ovules are little white semitransparent bodies, surrounded by a sort of projecting hood, beyond which a narrow papilla projects: this papilla is always turned towards the anthers. The latter are little flat parallelopipedons, rounded at the two ends; they consist of a membranous sac of great tenuity, in which are found numerous grains of spherical or elliptical pollen. (*Ann. Sc.*, n. s. vii. 227. t. 12, 13.) M. Fabre is represented as having proved experimentally that the latter impregnate the former; and he has traced the ovules from their first impregnation to their completion, and seen and described their germination. (*Id.* ix. 115, t. 13.) It appears that no trace of embryo is discoverable in the ripe seed.

In Pilularia the organs of reproduction lie in hairy oval cases, or sporangia, whose interior is divided into four cells filled with bags arranged in four lines as in parietal placentæ, some containing a germinating body or sporule, others filled with a powdery matter. The first have been regarded as pistils, the latter as anthers. But Mr. Valentine has shown, in a very detailed memoir, that the so called anthers are merely abortive spores, as I long ago suggested. (See *Linnæan Transactions*, vol. xviii. tt. 34 and 35.)

Salvinia and Azolla have been the subject of some elaborate observations by Mr. Griffith, (*Calcutta Journal*, vol. v.) He regards them as having true sexes, the male being certain necklace-shaped threads found at an early stage, in contact with what he denominates an orthotropous ovule. But strange to say, this so called ovule, instead of giving birth to an embryo, becomes the parent of reproductive bodies of two totally different kinds, having not even the smallest resemblance the one to the other, although the matrix out of which they are evolved is identical at an early period of the organisation.

The following is the substance of his descriptions of Salvinia and Azolla:—

Salvinia.—Male organs? articulated hairs on the stalks of the ovule, each joint containing a nucleus and a brownish fluid; Ovula nearly sessile, concealed by the roots, and partly covered with hairs; tegument open at the top; mature reproductive organs solitary, or in racemes of 3-5, about the size of a pea, covered with brown rigid hairs. The upper ones of each raceme, (or lowest as regards general situation), contain innumerable spherical bodies, of a brownish colour and reticulated cellular surface, terminating capillary simple filaments. These again contain a solid whitish opaque body. The other, which occupies the lowest part of the raceme, and which is the first and often the only one developed, is more oblong, containing 6-18 larger, oblong-ovate bodies, on short stout compound stalks: colour brown, surface also reticulated. Each contains a large, embossed, opaque, ovate, free body, of a chalky aspect: it is three-lobed at the apex, and contains below this a cavity lined by a yellowish membrane, filled with granular and viscid matter and oily globules.

Azolla.—The growing points present a number of minute confervoid filaments, the assumed male organs, which at certain periods may be seen passing into the foramen, the ovula becoming resolved into their component cells within the cavity of that body; organs of reproduction in pairs, attached to the stem and branches, one above the other, concealed in a membranous involucrum; ovula atropous, oblong-ovate, with a conspicuous foramen and nucleus, around the base of which are cellular protuberances; capsules of each pair either difform,—in which case the lowest one is oblong-ovate, the upper globose,—or both of either kind, generally perhaps the globose, presenting at the apex the brown remains of the foramen, and still inclosed in the involucrum; upper half generally tinged with red; the oblong-ovate capsule opens by circumcision; with the apex separate the contents, which consist of a large yellow sac contained in a fine membrane, the remains of the nucleus (or the secondary capsule). The sac is filled with oleaginous granular fluid, and surmounted by a mass of fibrous tissue, by which it adheres slightly to the

calyptra; on the surface of the fibrous tissue are nine cellular lobes (the three upper the largest), which, when pulled away, separate with some of the fibrous tissue, and so appear provided with radicles. The globose capsule has a rugose surface from the pressure of the secondary capsules within; these are many in number, spherical, attached by long capilliform pedicels to a central much branched receptacle; each contains two or three cellular masses, presenting on their contiguous faces two or three radiciform prolongations. In their substance may be seen imbedded numerous yellow grains, the spores.

I profess myself unable to understand in what respects the parts here called males, females, ovules, capsules, &c. resemble those organs except in name. Indeed Mr. Griffith himself could not help feeling the weakness of his case when he observed that, "A difficulty may be considered to be presented by the existence of the hairs round the base of the ovula. For these in their structure resemble what I suppose to be the male organs of Ferns, and also the anthers of certain Mosses and Hepaticæ; although the terminal cell presents less granular matter than usual. In respect of the supposed males, Azolla presents greater analogies with phanerogamous plants, than either Musci or Hepaticæ, in which nothing analogous to pollen grains has been, I believe, yet observed in the anther; which again can scarcely in all cases be considered a grain of pollen, the view suggested by the contents. Still even with the objections before mentioned the analogies are as tenable, I think, as those existing between the pistilla of Mosses and of phanerogamous plants; those organs in the former being originally closed, in the latter, theoretically at least, originally open. General objections may also be raised from the fact of moniliform filaments similar to those of Azolla having been found on the capsule of Salvinia, unconnected apparently with fecundation, and on the dissimilarity of the supposed fecundating process in the two genera." Opinions in which I quite concur, regarding them indeed as being fatal to a sexual theory in this case.

It has been thought that of the two kinds of grains or bodies above mentioned, the smaller are males and the larger females; which has been supposed to be proved by the

experiments of Savi of Pisa. This observer introduced into different vessels, 1. the granules; 2. the grains; and, 3., the two intermixed. In the first two nothing germinated; in the third the grains floated to the surface and developed themselves perfectly. The observations have, however, been repeated by Duvernoy without the same result; and it is clear that Mr. Griffith's observations are entirely opposed to the view entertained by Savi, and Adolphe Brongniart, who thus describes the reproductive bodies of Salvinia and Azolla. In these genera he found at the base of the leaves membranous involucres of two sorts, containing different organs. One includes a bunch of cases (*sporangia*, Martius), containing only one grain in Salvinia, and from six to nine in Azolla. The integument of these cases is thin, reticulated, brownish, and does not swell in water: the pedicel which supports them appears, in Salvinia, to communicate laterally with the case. The other involucres, which are supposed to be male organs, have a very complex structure, and have been well observed by Brown. In Salvinia they contain a great number of spherical granules, attached by long pedicels to a central column: these granules are much smaller than the grains; their surface is reticulated in like manner, and they do not burst by the action of water.

Of Isoetes the evidence as to sexuality is equally unsatisfactory. "Delile has published an account of the germination of Isoetes setacea, from which it appears that its sporules sprout upwards and downwards, forming an intermediate solid body, which ultimately becomes the stem, or corm; but it is not stated whether the points from which the ascending and descending axes take their rise are uniform. In Pilularia, Mr. Valentine finds that germination takes place invariably from a fixed point. Delile points out the great affinity that exists between Isoetes and Lycopodium, particularly in the relative position of the two kinds of reproductive matter. In Lycopodium, he says the pulverulent spore-cases occupy the upper ends of the shoots, and the granular spore-cases the lower parts: while, in Isoetes, the former are found in the centre, and the latter at the circumference. If this comparison is good, it will afford some

evidence of the identity of nature of these bodies, and that the pulverulent ones are at least not anthers, as has been supposed; for in Isoetes the pulverulent inner bodies have the same organisation, even to the presence of what has been called their stigma, as the outer granular ones; so that, if Isoetes has sexes, it will offer the singular fact of its anther having a stigma. The anatomy of Isoetes is described by Mohl in the *Linnæa*, xiv. 181." (*Vegetable Kingdom*, p. 73).

3. The Muscal Alliance.*

(*Urnmosses, Splitmosses, Horsetails, Scalemosses, Liverworts, and Crystalworts.*)

In the structure of Urnmosses (Bryaceæ or Musci) and Splitmosses (Andræaceæ), neither vessels nor woody tissue are employed. Their stem consists of elongated cellular tissue, from which arise leaves also composed entirely of cellular tissue without woody tissue; the nerves, as they are called, or, more properly speaking, ribs, which are found in many species, being formed by the approximation of longer cells than those which constitute the principal part of the leaf. The leaves are usually a simple lamina; but in Polytrichum and a few others they are furnished with little plates called lamellæ, running parallel with the leaf, and originating in the upper surface.

At the summit of some of the branches of many species are seated certain organs, which are called male flowers, but the true nature of which is not understood. They are possibly organs of reproduction of a particular kind, for both Mees and Haller are recorded to have seen them produce young plants. Agardh says they have only the form of male organs; and that they really appear to be gemmules. By Hedwig they were called *spermatocystidia;* by others *staminidia* or *antheridia.* They are cylindrical, articulated, clavate, membranous bodies, opening by an irregular perforation at the apex, and discharging a mucous granular fluid. Among them are found slender, pellucid, jointed threads,

* Vegetable Kingdom, p. 54.

which are abortive antheridia. Unger and Meyer have found what they call spermatic animalcules in the antheridia of Sphagnum and Hypnum. (*Comptes Rendus,* vi. 632.) But such bodies appear, notwithstanding their active motion, to be nothing more than loose spires.

Whatever may be the nature of these organs, there is no doubt of the reproductive functions of the contents of what is named the *sporangium, theca,* or *capsule,* which, in Urn-mosses, is a hollow urn-like body, containing *sporules:* it is usually elevated on a stalk, named the *seta,* with a bulbous base, surrounded by leaves of a different form from the rest, and distinguished by the name of *perichætial* leaves. If this sporangium be examined in its youngest state, it will be seen to form one of several small sessile ovate bodies (*pistillidia,* Agardh; *prosphyses,* Ehrhart; *adductores,* Hedwig), enveloped in a membrane tapering upwards into a point; when abortive they are called *paraphyses.* In process of time the most central of these bodies swells, and bursts its membranous covering, of which the greater part is carried upwards on its point, while the seta on which the sporangium is supported lengthens. This part, so carried upwards, is named the *calyptra:* if it is torn away equally from its base, so as to hang regularly over the sporangium, it is said to be *mitriform;* but if it is ruptured on one side by the expansion of the sporangium, which is more frequently the case, it is denominated *dimidiate.* When the calyptra has fallen off or is removed, the sporangium is seen to be closed by a lid terminating in a beak or rostrum: this lid is the *operculum,* and is either deciduous or persistent. If the interior of the sporangium be now investigated, it will be found that the centre is occupied by an axis, called the *columella;* and that the space between the columella and the sides of the sporangium is filled with sporules. The brim of the sporangium is furnished with an elastic external ring, or *annulus,* and an interior apparatus, called the *peristomium:* this is formed of two distinct membranes, one of which originates in the outer coating of the sporangium, the other in the inner coat; hence they are named the outer and inner peristomia. The nature of the peristomium is practically determined at the

period of the maturity of the sporangium. At this time both membranes are occasionally obliterated; but this is an unfrequent occurrence: sometimes one membrane only remains, either divided into divisions, called teeth, which are always some multiple of four, varying from that number as high as eighty, or stretching across the orifice of the theca, which is closed up by it; this is sometimes named the *epiphragma* or *tympanum*. Most frequently both membranes are present, divided into teeth, from differences in the number or cohesion of which the generic characters of mosses are in a great measure formed. For further information upon the peristomium, see Brown's remarks upon Lyellia, in the twelfth volume of the *Linnean Transactions*.

M. Endlicher considers that the sporangium is formed by the adhesion of an external and internal series of organs; and he calls *sporangidium* the inner, to which the peristomium belongs. (*Genera Plantarum*, 46.) The interior of the sporangium is commonly unilocular; but in some species, especially of Polytrichum, it is separated into several cells by dissepiments originating with the columella. If at the base of the sporangium there is a dilatation or swelling on one side, this is called a *struma;* if it is regularly lengthened downwards, as in most of the Splachnums, such an elongation is called an *apophysis*.

The spores have no adhesion either to the sides of the sporangium or to the columella, but appear to be formed much in the same way as pollen. When they germinate they produce capillary, articulated, green, branched threads, resembling Confervæ; and the leaves eventually appear from the axils of such branches.*

From the foregoing description, it will be apparent, that

* "Mr. Drummond, in a paper published in the 13th volume of the *Linnæan Transactions*, proved, beyond a doubt, that the sporules of mosses germinate by emitting 'pellucid filaments' from any points on their surface. I have myself examined the germinating sporules of Funaria hygrometrica, and I found that the brown coat burst sometimes in two or three places, but most frequently in one only; and there protruded from each fissure a delicate transparent tube containing the moving particles, which had previously occupied the cavity of the sporules. These tubes, or, to speak with more precision, elongated cells, gradually increased in length, and, from exposure to light, became of a green colour.

the organs of reproduction of Urn-Mosses cannot be compared strictly to the parts of fertilisation of perfect plants. I must not, however, omit the opinion of other botanists upon this subject. The office of males has been supposed by Micheli to be performed by the paraphyses; by Linnæus and Dillenius, by the sporangia; by Palisot de Beauvois, by the sporules; by Hill, by the peristomium; by Kœlreuter, by the calyptra; by Gærtner, by the operculum; and, finally, Hedwig has supposed the males to be the antheridia. The female organs were thought by Dillenius and Linnæus to be assemblages of antheridia; by Micheli and Hedwig, the young sporangia; and, by Palisot de Beauvois, the columella. Mr. Griffith thought that the sexuality of Urn-mosses was established by a breaking up of the tissue terminating and closing the style (subsequently to the application of a particular matter,) whereby the style becomes a canal opening exteriorly; by the browning observable in the orifice of this canal extending downwards until it reaches the cavity, &c. But it seems to me that the observations of Mr. Valentine dispose of the question conclusively, until some further evidence shall have been produced.

"The most satisfactory refutation of the theory of Hedwig will be found in the anatomy of the pistillum, where the impregnation of the seeds is supposed by him to take place. It is strange that the structure of this organ should have been so long misunderstood; that the young theca, under the name of germen, should have been supposed to be concealed in the bosom of the pistillum; a supposition of which there is not the shadow of a proof. If we refer to the description in the first part of this paper, we shall find that the cavity of the pistillum is occupied, in the first instance, by a single cell; and that this cell always remains at the base of the seta, where it may be found to the very last, tipping the conical extremity. We also find that before one particle of the theca can be formed, the seta must be developed; a process which, in many instances, occupies two or three

"They soon became jointed, from the addition of fresh cells at the extremities. They then began to branch, and after a time produced leaves." (*Valentine in Linn. Trans.* vol. xvii.)

months after the destruction of the pistillum. It is scarcely necessary to ask, how it is possible that the sporules can be impregnated before the theca, in which they are developed, is in existence. If sexes are to be found in Mosses, they must be sought in the theca; and accordingly we find that various botanists, probably impressed with this idea, have named in succession all the different parts of this organ as performing the function of the anthers. Some have fixed on the columella; others on the peristome; others on the operculum. It is altogether unnecessary to enter on an examination of the truth of these various hypotheses, as their original proposers have adduced so little in their support, that no one at present considers them worth the slightest attention." (*Linnæan Transactions*, vol. xvii.)

Mr. Valentine not only thus disproves the possibility of the parts called Sexes in Urn-mosses being so; but supports the opinion of Mohl that their sporules, and he adds those of all cellular plants, are analogous to the pollen of the Vasculares, slightly modified by circumstances, but agreeing in every essential particular.

"The analogy of the development of the sporules to that of pollen is very striking," he observes, "even to a superficial observer, and has not escaped the notice of botanists. A section of the anther of the common garden variety of Primula vulgaris, taken from a bud when about the size of a small pin's head, exhibits a structure which may be compared to a section of the theca of Polytrichum. In the former we find an axis of dense tissue (the connectivum) surrounded by the cuticle. This axis is not central, but placed nearer to the cuticle, on the back of the anther, and may be considered as the columella, whilst the cuticle will represent the theca. A separation of the tissue gradually takes place, in four distinct points, nearly at equal distances from the axis. As the axis is not centrical, these points lie towards the front of the anther. Between each of these points the cuticle is furrowed longitudinally, so that the section has somewhat of a quadrangular figure. The theca of Polytrichum merely differs from this in having a complete separation of its tissue all round the axis, instead of in four points only. The spaces

caused by the separation (not dissolution) of the tissue, gradually enlarging, form the cells of the anther, in which the viscid secretion takes place. This secretion is afterwards converted into pollen, in a manner similar to that in which the sporules are formed. When the anther is nearly ripe, a still further separation of the tissue takes place, and the four cells become two. When perfectly mature, these cells dehisce longitudinally at the lateral furrows. In Buxbaumia the theca frequently dehisces longitudinally after the manner of some anthers; whilst in Solanum the anther dehisces by a pore at the apex, thus approaching the ordinary dehiscence of the theca. The lining of the cells, or Endothecium of Purkinje, may be considered analogous to the columellar membrane." (*Linn. Trans.*, vol. xvii.)

Mr. Valentine afterwards supported these views by new observations, and at considerable length. I can only quote a part of the evidence on which he believes that the truth of his opinion is established.

"The analogy," he observes, "which exists between sporules and pollen is so remarkable, and the particulars so numerous, that the essential identity of the two can, as I conceive, be scarcely a matter of opinion. In the first place, the sporules are formed in thecæ, which have a great resemblance to some anthers. They are in most instances surrounded by a perichætium, which is a collection of modified leaves analogous to the perianth. They are either sessile, or seated on a stalk or seta, which may be named the filament. In Sphagnum the theca is elevated on a pedicel or leafless prolongation of the axis, of which peculiarity the anther of Euphorbia is a parallel instance. The thecæ are one-celled, yet they have a columella, which may be likened to the connectivum; and, although the connectivum usually divides the anther into two cells, Callitriche is an instance in which there is but one cell; and there are examples in which the cavity is spuriously divided into four cells, as in Tetratheca, which, in this respect, resembles the theca of Polytrichum; and in the fact of evacuating its contents by a single pore, resembles the general structure of thecæ. All thecæ are lined by a distinct membrane, and so nearly does this resemble the endothecium

of an anther, that in Jungermannia multifida its tissue is fibrous. The remarkable manner of the development of sporules and pollen is a most convincing analogy; they are secretions in the cellules which occupy the interior of the theca or anther, and are the only instances on record within my knowledge, of organised secretions in the cavities of simple cellules. Although the tetrahedral union of both sporules and pollen is almost always dissolved at an early period, yet, in some instances, as in Œdipodium and Erica Tetralix, it remains at maturity. Again, neither sporules nor pollen ever have the slightest apparent organic connexion with the parent plant,—a most remarkable coincidence. Then, to apply a chemical test, if sulphuric acid be applied to the sporules, the same phenomena occur as when it is applied to pollen. The effects of this test vary according to the nature of the contents of the sporule, and the manner of its application, which must be carefully regulated to insure a satisfactory result." The sporules of Jungermannia complanata, one of the Scale-mosses, "in their natural state, are of a rich olive-brown colour, and are completely filled with minutely granular matter. On the addition of a small portion of acid a few of them immediately burst, and the contents are scattered, but the majority acquire a border of a deep red colour, the contents appearing to be collected more towards the centre of the cavity, and they become more irregular in shape, with a projection on one side. Upon the addition of a little more acid the outer coat is slowly ruptured, and the contents are gradually squeezed out, the passage appearing to be a work of great labour, giving an observer the idea of parturition in animals. When the contents are nearly out the action is more rapid, and they are ejected with force, the sporule recoiling and contracting the fissure with a spring, unless, as is sometimes the case, the sporule is so much lacerated as to lose its elasticity."

Lastly, "the sporules of Mosses and of some other tribes commence their germination by the emission of the internal lining membrane in the form of a tube, which is exactly analogous to the pollen-tube. In the Mosses these tubes increase by the addition of a series of fresh tubes at their

extremities, and at length a bud containing the rudiments of stem, leaves, and roots is formed, which may be considered analogous to the embryo or young bud, in the seed of more highly organised plants." (*Linn. Trans.* vol. xvii.)

Mr. Thwaites, however, supports the sexuality of the antherids and pistillids of Mosses on new grounds, and with so much skill that we should leave the subject very incomplete if we did not give his ingenious views nearly in his own words. After observing that he thinks it probable that the conjugation of Brittleworts will throw light upon the real nature of the so called antheridia and pistillidia (*archegonia*) of Mosses, he proceeds thus:—"The paper on this subject by Mr. Valentine would seem to settle the point that there can be no impregnation of the contents of the moss-capsule by the introduction into its cavity of any external substance, after the formation of the sporules. On the other hand, the learned authors of the *Bryologia Europæa* state with emphasis that certain species of Mosses, which are dicœcious, —that is, some plants of the same species bearing antheridia only, and others only archegonia,—do not bear fruit unless the male plants (those with antheridia) are in the neighbourhood of the plants possessing archegonia. It is perhaps not impossible to reconcile these, at first sight, apparently conflicting opinions. It may be that impregnation takes place before the production of the capsule; that the cell from which the capsule, with its seta, &c., is developed corresponds with the sporangium of the Diatomaceous plant, or the embryonic cell of the flowering plants; that this cell contains a mixed endochrome derived partly from the antheridia; and that the entire capsule (with its contents, appendages, &c.), the further development of this primordial cell, corresponds to a perfect seed of the flowering plant, or to the aggregate of the sporangial frustules of a Diatomaceous plant. It is true that in some of the Mosses the structure of the capsule appears very complicated, but it is upon a very simple type, as shown in other species; and, moreover, the sporangial frustules of the Diatomaceous plant possess cell-walls as highly developed as occur in any other phase of the species. In some of the Conjugatæ there is

also a division of the reproductive mass before it escapes from the plant, so that the numerous sporules of the Moss furnish no argument against the hypothesis just advanced. As a further argument in favour of the idea of the capsule of the Moss being the product of a mixed endochrome, it is stated by Bruch and Schimper that the capsule itself is not developed unless the two so-called sexes of the species are in proximity." (*Annals of Natural History*, i. 165, n. s.)

For observations on the morphology of Urn Mosses the reader is referred to the *Vegetable Kingdom*, p. 65.

In SPLIT MOSSES (Andræaceæ) the sporangium is not an urn-like case, but splits into four valves, cohering by the operculum and base.

In HORSETAILS (Equisetaceæ) the stem is hollow, jointed, and bears a toothed sheath at each joint. The cylinder of the stem is pierced by longitudinal fistulæ, which alternate with furrows on the outside of the stem; there is also a bundle of ringed ducts connected with the fistulæ.

The organs of reproduction are arranged in a cone, consisting of scales bearing on their lower surface an assemblage of cases, called *sporangia*, *thecæ*, *folliculi*, or *involucra*, which dehisce longitudinally inwards. In these sporangia are contained two sorts of granules; the one very minute and lying irregularly among a larger kind, wrapped in two filaments, fixed by their middle, rolled spirally, having either extremity thickened, and uncoiling with elasticity. By Hedwig the apex of the larger granules was supposed to be a stigma, and the thickened ends of the filament anthers, the small granules being the pollen. It is certain that the larger granules, round which the elastic filaments are coiled, are the reproductive particles. Mr. Griffith states that the club-shaped bodies which Hedwig referred to stamens are in reality analogous to elaters, and are developed in or on a loose membranous coat, and later than the central body, spore, or seed. This statement has been confirmed by Henderson and Mohl.

SCALE MOSSES (Jungermanniaceæ) and LIVERWORTS (Mar-

chantiaceæ), differ much from each other in their organs of reproduction, while they have a striking resemblance in their vegetation. This latter, which bears the name of *frond* or *thallus*, is either a leafy branched tuft, as in Urn Mosses, with the cellular tissue particularly large, and the leaves frequently furnished with lobes, and appendages at the base, called *stipulæ* or *amphigastria*; or it is a flat lobed mass of green vegetable matter lying upon the ground.

In Jungermannia, that part which is most obviously connected with the reproduction of the plant, and which bears an indisputable analogy to the theca of Mosses, is a valvular brown case, called the capsule or conceptacle (*sporangium* or *sporocarpium*), elevated upon a white cellular tender seta, and originating in a hollow sheath or perichætium arising among the leaves. This conceptacle contains a number of loose spiral fibres (*elaters*), inclosed in membranous cases, among which sporules lie intermixed: when fully ripe, the membranous case usually disappears, the spiral fibres, which are powerfully hygrometric, uncurl, and the sporules are dispersed. When young, the conceptacle is inclosed in a membranous bag (*epigonium*), which it ruptures when it elongates, but which it does not carry upwards upon its point, as Mosses carry their calyptra. This part, nevertheless, bears the latter name.

Besides the conceptacles of Jungermannia, there are two other parts which are thought to be also intended for the purpose of reproduction: of these, one consists of spherical bodies, scattered over the surface of some parts of the frond, and containing a granular substance; the other is a hollow pouch, formed out of the two coats of a flat frond, and producing from its inside, which is the centre of the frond, numerous granulated round bodies which are discharged through the funnel-shaped apex of the pouch.

There are also other bodies situated in the axillæ of the perichætial leaves, called anthers (*spermatocystidia, antheridia, pollinaria, staminidia*), which "are externally composed of an extremely thin, pellucid, diaphanous membrane; within they are filled with a fluid, and mixed with a very minute granulated substance, generally of an olivaceous or greyish colour:

this, when the anther has arrived at a state of maturity, escapes through an irregularly shaped opening, which bursts at the extremity." Von Martius suspects these to be analogous to the sporangia of Azolla.

In Monoclea and Targionia organs nearly analogous to those of Jungermannia are formed for reproduction. In Targionia the antheridia are represented by M. Montagne as being embedded in discs very like the shields of Lichens. (*Ann. Sc.*, n. s. ix. 100.).

In Marchantia the frond is a lobed flat green substance, not dividing into leaves and stems, but lying horizontally upon the ground, and emitting roots from its under surface. The organs of reproduction consist, firstly, of a stalked fungus-like receptacle, carrying on its apex a calyptra, and bearing sporangia on its under side; secondly, of a stalked receptacle, plane on the upper surface, with oblong bodies embedded vertically in the disc, and called anthers; thirdly, "of little open cups (*cystulæ*), sessile on the upper surface of the fronds, and containing minute green bodies (*gemmæ*), which have the power of producing new plants." The first kind is usually considered a female flower, its spores being intermixed with elaters; the second male, and the third viviparous apparatus. In the opinion of many modern botanists, the granules of both the first two are spores: about the function of the last there is no difference of opinion. Mirbel considers the first two to be male and female; but, whatever their functions may be, in structure there is but little analogy between them and the organs of more perfect plants. Meyen describes the so called spermatic animalcules, resembling the genus Vibrio, as occupying the interior of each grain of the supposed pollen in Marchantia polymorpha. (*Comptes Rendus*, vi. 533). They are figured by him in the *Annales des Sciences*, n. s. x. 319, t. 3, from Marchantia polymorpha, Chara vulgaris, Sphagnum acutifolium, and Hypnum triquetrum. Their real nature has been already explained.

In Anthoceros, while the vegetation is the same as in Marchantia, the organs of reproduction are very different. They consist of a subulate column, issuing from a perichætium perpendicular to the frond, and dividing half way into two

valves, which discover, upon opening, a subulate columella, to which sporules are attached without any elaters. There are also cystulæ upon the frond, in which are inclosed pedicellate reticulated bodies, called anthers.

Sphærocarpus consists of a delicate roundish frond, on the surface of which are clustered several cystulæ, each of which contains a transparent spherule filled with sporules.

In Riccia the spherules are not surrounded by cystulæ, but immersed in the substance of the frond.

4. The Lichenal Alliance.*

(*Lichens.*)

These have a lobed frond or *thallus* (or *blastema*), the inner substance of which consists wholly of reproductive matter, that breaks through the upper surface in certain forms which have been called fructification. These forms are twofold; firstly, *shields* (*scutella* or *apothecia*), which are little coloured cups or lines with a hard disc, surrounded by a rim, and containing *asci*, or tubes filled with sporules; and, secondly, *soredia*, which are heaps of pulverulent bodies scattered over the surface of the thallus. The nomenclature of the parts of Lichens has been excessively extended beyond all necessity: it is, however, desirable that it should be understood by those who wish to read the systematic writers upon the subject.

1. *Apothecia*, are shields of any kind.
2. *Perithecium*, is the part in which the asci are contained.
3. *Hypothecium;* the substance that surrounds, or overlies the perithecium, as in Cladonia.
4. *Scutellum*, is a shield with an elevated rim, formed by the thallus. *Orbilla*, is the scutellum of Usnea.
5. *Pelta*, is a flat shield without any elevated rim, as in the genus Peltidea.
6. *Tuberculum*, or *Cephalodium*, is a convex shield without an elevated rim.
7. *Trica*, or *Gyroma*, is a shield, the surface of which is grooved with sinuous concentric furrows.

* Vegetable Kingdom, p. 45.

8. *Lirella,* is a linear shield, such as is found in Opegrapha, with a channel along its middle.
9. *Patellula;* an orbicular sessile shield, surrounded by a rim which is part of itself, and not a production of the thallus, as in Lecidea. *D. C.*
10. *Globulus;* a round deciduous shield, formed of the thallus, and leaving a hollow when it falls off, as in Isidium. *D.C.*
11. *Pilidium;* an orbicular hemispherical shield, the outside of which changes to powder, as in Calycium. *D. C.*
12. *Podetia;* the stalk-like elongations of the thallus, which support the fructification in Cenomyce.
13. *Scypha* (*oplarium,* Neck.), is a cup-like dilation of the podetium, bearing shields on its margin.
14. *Soredia* (*globuli, glomeruli*), are heaps of powdery bodies lying upon any part of the surface of the thallus. The bodies of which the soredia are composed are called *conidia* by Link, and *propagula* by others.
15. *Cystula,* or *Cistella;* a round closed apothecium, filled with sporules, adhering to filaments which are arranged like rays around a common centre, as in Sphærophoron.
16. *Pulvinuli,* are spongy excrescence-like bodies, sometimes rising from the thallus, and often resembling minute trees, as in Parmelia glomulifera. *Greville.*
17. *Cyphellæ,* are pale tubercle-like spots on the *under* surface of the thallus, as in Sticta. *Grev.*
18. *Lacunæ,* are small hollows or pits on the *upper* surface of the thallus. *Grev.*
19. *Nucleus proligerus,* is a distinct cartilaginous body coming out entire from the apothecia, and containing the reproductive organs. *Grev.*
20. *Lamina proligera,* is a distinct body containing the reproductive organs, separating from the apothecia, often very convex and variable in form, and mostly dissolving into a gelatinous mass. *Grev.*
21. *Fibrillæ,* are the roots.
22. *Excipulus,* is that part of the thallus which forms a rim and base to the shields.
23. *Nucleus,* is the disc of the shield which contains the sporidia and their cases.

24. *Asci,* are tubes, in which the sporidia are contained while in the nucleus.
25. *Thallodes,* is an adjective used to express an origin from the thallus: thus, *margo thallodes* signifies a rim formed by the thallus, *excipulus thallodes* a cup formed by the thallus.
26. *Lorulum,* is used by Acharius to express a filamentous branched thallus.
27. *Crusta,* is a brittle crustaceous thallus.
28. *Gongyli,* or *Gonidia,* are granules, universally of a green colour; they lie either singly or in clusters beneath the cortical layer of the thallus, or break out in clusters called soredia, or in cups called cyphelia.

5. The Fungal Alliance.*

(*Fungi.*)

These plants consist of little besides cellular tissue, among which spores, or sporidiferous asci are generated. Some, of the lowest degree of development, are composed only of a few cellules, as Mucor, of which one is larger than the rest, and contains the spores; others are more highly compounded, consisting of myriads of cellules, with sporidia lying in cases, or *asci.*

Sexes have been generally denied to Fungals. M. Leveillé has shown that, in the Agaric and some other high forms of the order, there are two sorts of organs; the one prominent cells containing a highly attenuated form of matter, and the other undoubtedly spores, and that these two kinds of organs are intermingled with each other; and these bodies have been supposed to represent a sexual apparatus. There does not, however, exist the slightest proof of their nature: and they appear to be wholly absent in all the low Fungals.

Corda has shown that spiral-threaded cells, analogous to elaters, exist in the genus Trichia. This, however, had been observed before by the younger Hedwig and Kunze.

It is exclusively among these plants that we meet with

* See "Vegetable Kingdom," p. 29.

cases of parasitism upon living animal bodies. The silkworm, and hymenopterous insects, are destroyed by the action of certain species of Botrytis in the one case, and Sphæria in the other, which attack them while alive.

Notwithstanding the extreme simplicity of these plants, writers upon Fungi have contrived to multiply the terms relating to them in a remarkable manner. The following are those which are most usually employed.

1. The *Pileus,* or *Cap,* is the uppermost part of the plant of an Agaricus, and resembles an umbrella in form.
2. The *Stipes,* is the stalk that supports the pileus.
3. The *Volva,* or *Wrapper,* is the involucrum-like base of the stipes of Agaricus. It originally was a bag enveloping the whole plant, and was left at the foot of the stipes when the plant elongated and burst through it.
4. The *Velum,* or *Veil,* is a horizontal membrane, connecting the margin of the pileus with the stipes: when it is adnate with the surface of the pileus, it is a *velum universale;* when it extends only from the margin of the pileus to the stipes, it is a *velum partiale.*
5. The *Annulus,* is that part of the veil which remains next the stipes, which it surrounds like a loose collar.
6. *Cortina,* is a name given to a portion of the velum which adheres to the margin of the pileus in fragments.
7. The *Hymenium,* is the part in which the reproductive organs immediately lie; in Agaricus, it consists of parallel plates, called *lamellæ,* or *gills.* These are *adnate* with the stipes, when the end next it coheres with it: when they are adnate, and at the same time do not terminate abruptly at the stipes, but are carried down it more or less, they are *decurrent;* if they do not adhere to the stipes, they are said to be *free.*
8. *Stroma,* is a fleshy body to which flocci are attached; as in Isaria and Cephalotrichum.
9. *Flocci,* are woolly filaments found mixed with sporules in the inside of many Gastromyci. The same name is also applied to the external filaments of Byssaceæ.
10. *Orbiculus,* is a round flat hymenium contained within the peridium of some fungi; as Nidularia. *W.*

11. *Nucleus,* is the central part of a perithecium.
12. *Sporangium,* is the external case of Lycoperdon and its allies; it is, however, best employed to designate the false peridium of Mucorini.
13. *Sporangiolum,* its diminutive.
14. *Peridium, Peridiolum,* terms usually substituted for Sporangium and Sporangiolum.
15. *Perithecium,* is a term used to express the part which contains the reproductive organs of Sphæria and its co-ordinates.
16. *Ostiolum,* is the orifice of the perithecium of Sphæria.
17. *Spherula,* is a globose peridium, with a central opening through which sporidia are emitted, mixed with a gelatinous pulp.
18. *Capillitium,* is a kind of purse or net, in which the spores of some Fungi are retained; as in Trichia. *W.*
19. *Trichidium,* or *Pecten,* is a tender, simple, or sometimes branched hair, which supports the spores of some Fungi; as Geastrum. *W.*
20. *Asci,* are the tubes in which the sporidia are placed; *ascelli* or *thecæ* are the same thing.
21. *Paraphyses,* barren asci, or at least threads accompanying the asci.
22. *Spores;* the reproductive organs when produced at the tip of a cell, without any external case or ascus.
23. *Sporidia;* spores contained in asci. *Sporidiola;* the nuclei of spores or sporidia.
24. *Episporium;* the membrane, usually double, which invests the Endochrome of the reproductive organs.
25. *Endochrome;* the granular contents of spores and sporidia.
26. *Nuclei;* bodies contained in the reproductive organs analogous to cytoblasts, and then called sporidiola, or mere oil globules.
27. *Sporules;* a term used variously by authors, but which is best confined to designate the component granules of the Endochrome.
28. *Thallus,* or *Thalamus,* is the bed of fibres from which many Fungi arise.

29. *Mycelia,* are the rudiments of Fungi, or the matter from which Fungi are produced.
30. *Cystidia,* are the projecting cells, or supposed male organs, of Agarics, &c.
31. *Sporophores* or *Basidia,* are the cells on the apex of which the spores of such plants are formed.

6. The Algal Alliance.*

(*Confervas, Seaweeds, &c.*)

These, with Fungi, constitute the lowest order of vegetable development: they vary from mere microscopic objects to a large size, and are composed of cellular tissue in various degrees of combination; some are even apparently animated, and thus form a link between the two great kingdoms of organised matter. Their spores are either scattered through the general mass of each plant, or collected in certain places which are more swollen than the rest of the stem, and sometimes resemble the pericarps of perfect plants.

The mode of propagation in Algals is extremely variable, but apparently always takes place by the formation of spores, either within the ordinary cells of the plant, or within sporangia of one kind or other. The Zygnemata have the curious attribute of forming their spores by the copulation of two contiguous branches.

The terms used in speaking of the parts of these plants are the following:—

1. *Gongylus;* a round hard body, which falls off from the mother plant, and produces a new individual: this is found in Fuci. *W.*
2. *Thallus;* the plant itself.
3. *Apothecia;* the cases in which the organs of reproduction are contained.
4. *Peridiolum,* Fr.; the membrane by which the spores are immediately covered.
5. *Granula;* large spores, contained in the centre of many Algaceæ; as in Gloionema of Greville. *Crypt. Fl.* vi. 30.

* See "Vegetable Kingdom," p. 8.

6. *Pseudoperithecium;* } terms used by Fries to express such
7. *Pseudohymenium;* } coverings of spores as resemble
8. *Pseudoperidium;* } in figure the parts named perithecium, hymenium, and peridium in other plants: see those terms.
9. *Sporidia;* granules which resemble spores, but which are of a doubtful nature. It is in this sense that Fries declares that he uses the word: vide *Plant. homonom.* p. 294. They are also called *Sporæ.*
10. *Phycomater,* Fries; the gelatine in which the spores of Byssaceæ first vegetate.
11. *Vesiculæ;* inflations of the thallus, filled with air, by means of which the plants are enabled to float.
12. *Hypha,* Willd.; the filamentous, fleshy, watery thallus of Byssaceæ.
13. *Sporangia;* any kind of case not obviously a joint of the plant, within which spores are generated.
14. *Coniocysta;* tubercle-like closed apothecia, containing a mass of spores; the same as sporangium.

Dr. Harvey thus describes their reproductive organs, (*British Algæ,* xx.)

"In fructification we find many modifications of structure, without much real difference either in the manner in which the fruit is perfected, or in the seed that is produced. The seed that is finally formed in all the tribes of genuine Algæ, from which I exclude the Diatomaceæ, appears pretty nearly to agree in structure, and to consist of a single cellule or bag of membrane, filled with a very dense and dark coloured granular or semifluid mass, called the endochrome. This seed on germination produces a perfect plant, resembling that from which it sprung. Nothing at all resembling floral organs has been noticed in any, and all that we know of the fructification is, that it takes place with regularity, arising from the same parts of the frond, and having the same appearance in plants of the same kind. Its growth may be watched from the commencement, when, what we may call the ovule, or germ of the future seed, begins to swell. But nothing whatever has been ascertained that throws the smallest light on the process of fecundation. In some

instances it is true, as for example, in Zygnema, the seed is formed from the union of the matter in one filament to that in another, and it has been observed, that the joints of one filament uniformly give out, and that those of another uniformly receive; but before conjugation no difference whatever can be perceived between the two filaments. This, which occurs in a tribe of very low organisation, affords the nearest analogy that has yet been noticed with what takes place in higher plants. If it have any real affinity with that process, we may fairly expect the discovery of sexes in the more perfect tribes; but nothing at all resembling male flowers has been noticed in these. Some old authors certainly invested the air-vessels of Fucus, and others the tufts of hairs that clothe the surface of some species, with this character, but both opinions have been long since given up as untenable. That a transmission of the endochrome from one cellule to another, prior to the formation of seed, occurs in all Algæ, seems probable from the fact, that the cellules immediately surrounding the seeds are always colourless and empty, but there is nothing as yet known to prove that one cellule is less adapted than another to receive the endochrome, and form the future embryo,—nothing to show that there is any distinction into male and female.

Many Algæ, perhaps all of the red series (Rhodospermeæ) are furnished with a double system of fructification, called primary and secondary fruit; terms which are given for convenient distinction, without intending them to mean that one is of more or less importance than the other, for the seed formed in each is equally capable of producing a new plant, as Mr. J. G. Agardh has clearly shown. What is called primary is generally placed in capsules, which are either globose or pitcher-shaped, or at least a large number of seeds are collected into compact, sphærical clusters, and immersed in the frond; in the secondary, on the contrary, the seeds, which are commonly called granules, are usually placed in cloud-like or defined patches called sori, or in distorted portions of the frond; but in many genera, as in Odonthalia, Dasya, Griffithsia, &c., proper receptacles of various shapes are formed for their reception. The production of granules

in the plants in which it occurs, seems by the regularity with which it takes place to be as essential to the propagation of the species as that of the sporules or primary seeds. However distorted the form of the receptacle may be in which the granules are immersed, there is no reason to suppose that they originate in disease, for they are produced with so much constancy that they furnish us with some of the best distinguishing characters for genera. But there is a really anomalous structure connected with an imperfect attempt at fructification not uncommonly found on several Florideæ, especially those of the structure that we have above compared to that of exogens, as Chondrus, Gigartina, &c. This, to which Agardh gives the name of *nemathecium*, is a wart-like protuberance, of a very irregular figure and generally large size, consisting entirely of concentric filaments with coloured joints, in all respects resembling those that form the periphery, but much longer. To the naked eye these warts often strongly resemble capsules, and as such have been frequently described, but they never contain any seeds. The so-called capsules of Chondrus dilatatus are of this nature. It is rare that dependence can be safely placed on bodies of so anomalous a nature as furnishing specific, much less generic characters, but in Gigartina plicata and Griffithsiæ, plants in which no other effort at fructification has yet been noticed, they afford good specific marks. In Griffithsia setacea, bodies (noticed in the description of that plant, p. 103), sometimes occur in the position of capsules, which have apparently the structure of nemathecia; but, judging from their position and size, I am more disposed to consider them viviparous capsules, in which the sporular mass has been converted into minute filaments whilst attached to the parent. Another anomalous body simulating fruit, if it be not a male flower, frequently occurs in some of the filamentous tribes, especially in the genus Polysiphonia (P. fastigiata, fibrata, fibrillosa, &c.), to which Agardh gives the name of antheridium. It is a minute pod-like or lanceolate body, of a yellow colour, containing a granular fluid, borne on the colourless, long-jointed fibres, that at particular seasons are found issuing from the tips of the branches in several, if not all Polysiphoniæ.

The nature of these minute organs deserves more attention than it has obtained, for they are produced with too much regularity to be regarded as accidental. On P. fastigiata they are so abundant as to give the frond a yellow colour to the naked eye."

In this description Dr. Harvey, like myself, rejects the hypothesis that sexes occur among Algals. A totally different view has been taken by MM. Decaisne and Thuret, whose account of what they imagine to be sexes I extract at length from the *Annales des Sciences*, vol. iii. of the third series.

"The conceptacles of Fucaceæ are bisexual or unisexual. The first contain both spores and antheridia, and in this case the plant is said to be hermaphrodite (*Ex.* Fucus canaliculatus, tuberculatus, Halidrys siliquosa). The latter contain neither of these organs, and two cases may then be distinguished: sometimes (as may be occasionally seen in Fucus nodosus) two sorts of receptacles are found on the same stem, the one bearing male and the other female conceptacles: the plant is then monœcious. At other times the same stem bears but one and the same sort of conceptacle, (as in Fucus serratus, vesiculosus), in which case the plant is diœcious. These definitions appeared to us to require explanation; but they are far from being accurate; for as we descend the scale of vegetation, organisation becomes more and more simple, the inflorescence is confounded with the flower, and the terms used to express the organisation of comparatively perfect plants cannot be applied with precision to plants which are much less developed.

"As examples of diœcious Fuci, we may give F. serratus and F. vesiculosus. It is, indeed, not uncommon to find hermaphrodite conceptacles in individuals allied to the latter species; but it must be remembered that under the name of F. vesiculosus many species are confounded, which were formerly distinguished, and which must again be admitted as so many different types, and not, as at present, as mere varieties of one and the same thing. It is, however, very easy to distinguish the male receptacles in unisexual Fuci by the orange tint of their antheridia. The latter consist of ovoid vesicles containing a white substance scattered over with red

granules; they are borne on branched articulated hairs, which almost completely fill the conceptacle. Each antheridium is itself inclosed in another perfectly transparent vesicle, a sort of perispore which bursts and thus enables the antheridium to escape into the surrounding fluid. If the male fronds are exposed for some time to the action of air, the antheridia, expelled *en masse* through the orifice of the conceptacles, are seen to form small orange-red heaps on the thallus. This observation did not escape Réaumur. 'If,' says he, 'you take species of Fucus (serratus and vesiculosus) out of the water in which they grow, when the ends of their leaves are swollen, when the plants begin to get dry, a drop of a thick orange-yellow liquid is seen at the opening of each capsule. This liquor, no doubt, comes from within the capsule, since it is found at the orifice of the latter.' If one of these red drops is placed under the microscope, it will be found to be entirely composed of antheridia, and a number of transparent corpuscles, shaped something like a bottle, and which move about with great activity, will be seen to come out of their extremities. Each of these corpuscles contains a red granule which seems (perhaps from some optical effect) to form a protuberance on its side. In contact with ammonia these corpuscles are dissolved (*décomposé par diffluence*), the red granule alone remaining. Their organs of locomotion are composed of two very delicate ciliæ of unequal length; the shortest appears to be inserted towards the narrowest end of the body, the other, much longer than the first, seems to proceed from the red granule; during progression the shorter is always foremost, and the longer hindmost: this curious arrangement reminds one very forcibly of what has been observed in certain Infusoria of the monad family, in the Cercomonas and the Amphimonas of M. Dujardin. We ought also to notice the analogy between these corpuscles and the so called spermatic animalcules of Chara, Mosses, and Liverworts. These curious beings have been long studied by one of us; two locomotive ciliæ inserted near the end of a filiform spiral body have been found everywhere, in the Charas as well as in Mosses, Jungermannias, Marchantias, &c. This structure is, no doubt, very different

from what has been observed in the Fucus, but then a Fucus is itself very different from a Moss or a Liverwort. To those who say that these corpuscles are sporidia, we have only to answer, that this opinion, far from being supported by any direct proof, seems altogether incompatible with the extreme smallness and simplicity of the structure of these bodies. As to the hypothesis that they unite together to form a *propagulum*, this is altogether a piece of imagination that is not confirmed by a single observation. On the contrary, these corpuscles seem to be rather quickly decomposed, and form, at the bottom of the vessel in which they are collected, a layer of inert granules which soon disappear entirely. It is almost superfluous to add that we have never discovered any appearance of germination.* We think, on the whole, that we shall not be far wrong if we regard these vesicles, so improperly called *microphytes*, as analogous to the antheridia of other Cryptogams, but we cannot for a moment admit that these vesicles perform the functions of sporangia, or the corpuscles those of spores or sporidia.

"The female receptacles are distinguished by their olive colour. If they are examined when the plants are left dry by the receding tide, their spores will be seen to come briskly out of the conceptacles, and form, at the orifices of the latter, little heaps which soon fall on, and remain attached to, the neighbouring substances. If a thin slice is then made, the conceptacles will be found to be covered with a more or less considerable quantity of empty perispores, the diameters of which seem to be less than those of the spores themselves. The opening of the perispore, especially, is at times so narrow that we cannot imagine the spore to have passed through it without supposing it to possess great contracting powers. The spore is as yet simple, although it presents well-marked traces of its approaching division. The membrane by which it is covered, at first thin and refracting, soon distends into a transparent epispore covered all over with ciliæ just like that of the spores of Vaucheria: but it differs from the latter in the spores of no Fucus having ever been seen, by us, to move.

"An extremely curious phenomenon is now manifested;

* For the supposed nature of these and all such corpuscles, see Vol. I.

we shall describe the appearances found in Fucus serratus, vesiculosus, and the other varieties referred to these species. The signs of division marked by furrows on the olive-coloured matter of the spore become more and more distinct, until they look like true partitions; the spore is then found to be divided into eight masses which gradually separate from each other, and then form as many smooth spherical sporules. The epispore is soon after destroyed, and each sporule begins to germinate.

"The germination of Fucus serratus takes place as follows:—About twenty-four hours after the division just described, a very small tumour appears on the surface of the sporule. At the end of forty-eight hours this tumour is elongated into a cylindrical tube filled with a quantity of olive yellow granules: a transverse partition is formed in the sporule which is thus divided into two hemispheres. After three days, another partition is formed at the entrance of the tube; the colour of the sporules remains unaltered. By the fourth day a new partition divides the mass into four equal parts, in each of which a sort of denser nucleus is observed. By the fifth day, the divisions are multiplied so as to part the sporule into six portions. While these changes are taking place the tube continues to grow, but without forming any partitions. These observations, it will be seen, differ from those of M. Agardh, who, by the bye, has clearly mistaken the germination of a sporule for that of a spore itself. (*Ann. des Sc. Nat.*, tom. vi. p. 209. tab. 15.)

"The spore of Fucus nodosus is divided into four sporules as has been observed by M. Crouan (*Ann. des Sc. Nat., 3d series*, tom. ii. p. 366. tab. 11). This plant is also peculiar in another way; it is sometimes diœcious, at others monœcious. Hence it is that it is sometimes found covered with male or female conceptacles only; whilst at others the two sexes are found on the same stem, but borne on distinct receptacles.

"Fucus canaliculatus and F. tuberculatus are both hermaphrodite. In the former, the antheridia are distinguished by their hyaline colour, and the corpuscles within them have not the red granule which was found in all the other Fuci. The spore, at the moment of its liberation, is marked by two

slight lateral depressions indicating its future division into two sporules. The whole contour of the epispore presents a large quantity of very delicate folds which disappear soon after the spore has fallen to the bottom of the water; the epispore then rapidly distends and forms round each sporule a large transparent limb covered all over with ciliæ.

"The conceptacles of Fucus tuberculatus are, as it were, divided into two parts; the upper half near the ostiole is covered with antheridia; the other half at the bottom of the conceptacle is reserved for the spores. We may compare this arrangement to the inflorescence of the fig. The spores seem to remain undivided and not to become broken up into sporules as in the other Fuci. However, we must add, that the specimens which we had the opportunity of examining were not sufficiently fresh to enable us to be certain on this point.

"The antheridia of this Algal are not, like those of the preceding species, formed of a double envelope; the interior vesicle is wanting, and that which we have compared to a perispore is alone to be found. The corpuscles expelled directly from the latter, remain for some time collected together, in a bunch, before they disperse in the water. We have observed the same thing in another Algal with hermaphrodite conceptacles (Halidrys siliquosa) the spores of which also appear to remain entire. The corpuscles are shaped rather differently from the others, and the arrangement of the ciliæ is precisely the inverse of that formerly described. The corpuscle, when in motion, turns upon itself, the longest cilia, which is agitated with great rapidity, being foremost, whilst the short one, inserted in the red granule, remains still.

"From what we have now said, it cannot, we think, be doubted that Fuci have a sexual apparatus analogous to that granted to exist in Charas, Mosses and Liverworts, a sexuality which is, it is true, as yet doubtful, and of which we have no other proof than the observations of MM. Bruch and Schimper on Encalypta streptocarpa." (*Bryologia Europæa, fascic.* iv.)

Finally, Mr. Thwaites is inclined to recognise a sexual element

in the lowest of all Algals, Brittleworts, or Diatomaceæ:—"In many of the Diatomaceæ," he says, "it is seen that at a certain period of the development of the species a union of the endochromes of two distinct frustules seems necessary for the continued existence of the species as well as for its reproduction. The physiologist will endeavour to arrive at some probable explanation of the reason why this mixture of endochromes is necessary, and he will feel it difficult to come to any other conclusion than this: namely, that in each of the conjugating endochromes an essential element must to some extent, probably very trifling, be wanting, whilst another essential element is in excess; and that a mixture of such an endochrome with another similarly conditioned, except that the quantities of such respective elements are reversed, must take place, in order to restore the equilibrium and enable the species to continue its existence. The circumstance of the mixed endochrome developing around itself a cell-wall precisely similar in every respect, except in size, to that of the ordinary frustule, would seem to indicate very slight, if any, difference in the qualities of their respective endochromes. The sporangium,—the product of this mixed endochrome,—undergoes fissiparous division, too, in like manner with the ordinary frustules, and is thus converted into a number of sporangial frustules. In what way the small ordinary frustules are produced from these has not yet been observed." (*Annals of Nat. Hist.*, i. 162, n. s.)

BOOK II.

PHYSIOLOGY; OR, PLANTS CONSIDERED IN A STATE OF ACTION.

CHAPTER I.

GENERAL CONSIDERATIONS.

Plants have been thus far considered merely with reference to their structure. Our next business is to inquire into the nature of their vital actions, and to make ourselves acquainted with what is known of the laws of vegetable life.

In explaining these things, it will be useful, in the first place, to give a summary exposition of the principal phenomena of vegetation, and then to support the statement by a detailed account of the more important proofs of all disputed points.

In this the student will be materially assisted by the *Physiologie Végétale* of De Candolle, a work of which it is difficult to speak in terms of sufficient eulogy, but which may be justly described as the most important production on the subject of Vegetable Physiology, which, at the time of its publication, had appeared since the *Physique des Arbres* of Duhamel.

I. If we place a seed (that of an apple, for instance) in earth at the temperature of 32° Fahr., it will remain inactive till it finally decays. But if it is placed in moist earth some degrees above 32°, and screened from the action of light, its integument gradually imbibes moisture and swells; the tissue is softened, and acquires the capability of stretching; the water is decomposed, and a part of its oxygen, combining

with the carbon of the seed, forms carbonic acid, which is expelled; nutritious food for the young parts is prepared by the conversion of starch into sugar; and the vital action of the embryo commences. It lengthens downwards by the radicle, and upwards by the cotyledons; the former penetrating the soil, the latter elevating themselves above it, acquiring a green colour by the decomposition of the carbonic acid they absorb from the earth and atmosphere, and unfolding in the form of two opposite roundish leaves. This is the first stage of vegetation; the young plant consists of little more than cellular tissue; only an imperfect development of vascular and fibrous tissue being discoverable, in the form of a sort of cylinder, lying just in the centre. The part within the cylinder, at its upper end, is now the pith, without it the bark; while the cylinder itself is the preparation for the medullary sheath, and consists of vertical tubes passing through and separated by cellular tissue.

The young root is now lengthening at its point, and absorbing from the earth its nutriment, which passes up to the summit of the plant by the cellular substance, and is, in part, impelled into the cotyledons, where it is aërated and evaporated, but chiefly urged upwards against the growing point or plumule.

II. Forced onwards by the current of sap, which is continually impelled upwards from the root, the plumule next ascends in the form of a little twig, at the same time sending downwards, in the centre of the radicle, the earliest portion of wood that is deposited, and compelling the root to emit little ramifications; and simultaneously the process of lignification is going on in all the tissue, by the deposit of a peculiar secretion in layers within the cells and tubes.

Previously to the elongation of the plumule, its point has acquired the rudimentary state of a leaf: this latter continues to develope as the plumule elongates, until, when the first internode of the latter ceases to lengthen, the leaf has actually arrived at its complete formation. When fully grown it repeats in a much more perfect manner the functions previously performed by the cotyledons: it aërates the sap that it

receives, and returns the superfluous portion of it downwards through the bark to the root; tubular tissue at the same time appears between the medullary sheath and the bark, thus forming the first ligneous stratum, a part of which is incorporated with the bark, the remainder forming wood.

During these operations, while the plumule is ascending, its leaf forming and acting, and the woody matter created by it descending, the cellular tissue of the stem is forming, and expanding horizontally, to make room for the new matter forced into it; so that development is going on simultaneously both in a horizontal and perpendicular direction. This process may not inaptly be compared to that of weaving, the warp being the perpendicular, and the weft the horizontal, formation. In order to enable the leaf to perform its functions of aëration completely, it is traversed by veins originating in the medullary sheath, and has delicate pores (*stomates*), which communicate with a highly complex pneumatic system extending to almost every part of the plant.

Simultaneously with the appearance of woody matter, the emission of young roots, and their increase by addition to the cellular substance of their points, take place. They thus are made to bear something like a definite proportion to the leaves they have to support, and with which they must of necessity be in direct communication.

After the production of its first leaf by the plumule, others successively appear in a spiral direction around the axis at its growing point, all constructed alike, connected with the stem or axis in the same manner, and performing precisely the same functions as have been just described. At last the axis ceases to lengthen; the old leaves gradually fall off; the new leaves, instead of expanding after their formation, retain their rudimentary condition, harden, and fold over one another, so as to be a protection to the delicate point of growth; or, in other words, become the scales of a bud. We have now a shoot with a woody axis, and a distinct pith and bark; and of a more or less conical figure. At the axil of every leaf a new growing point had been generated during the growth of the axis; so that the shoot, when deprived of its

leaves, is covered from end to end with little, symmetrically arranged, projecting bodies, which are the buds.

The cause of the figure of the perfect shoot being conical is, that, as the wood originates in the base of the leaves, the lower end of the shoot, which has the greatest number of strata, because it has the greatest number of leaves above it, will be the thickest; and the upper end, which has had the fewest leaves to distend it by their deposit, will have the least diameter. Thus that part of the stem which has two leaves above it will have wood formed by two successive deposits; that which has nine leaves above it will have wood formed by nine successive deposits; and so on: while the growing point, as it can have no deposit of matter from above, will have no wood, the extremity being merely covered by the rudiments of leaves hereafter to be developed.

If at this time a cross section be examined, it will be found that the interior is no longer imperfectly divided into two portions, namely, pith and skin, as it was when first examined in the same way, but that it has distinctly two internal, perfect concentric lines, the outer indicating a separation of the bark from the wood: and the inner, a separation of the wood from the pith: the latter, too, which in the first observation was fleshy, and saturated with humidity, is become distinctly cellular, and altogether or nearly dry.

III. With the spring of the second year, and the return of warm weather, vegetation recommences.

The uppermost, and perhaps some other, buds, which were formed the previous year, gradually unfold, and pump up sap from the stock remaining in store about them; the place of the sap so removed is instantly supplied by that which is next it; an impulse is thus given to the fluids from the summit to the roots; fresh extension and fresh fibrils are given to the roots; new sap is absorbed from the earth, and sent upwards through the wood of last year; and the phenomenon called the flow of the sap is fully completed, to continue with greater or less velocity till the return of winter. The growing point lengthens upwards, forming leaves and buds in the same way as the parent shoot: a horizontal increase of the whole of the

cellular system of the stem takes place, and each bud sends down organisable matter within the bark and above the wood of the shoot from which it sprang: thus forming on the one hand a new layer of wood, and on the other a fresh deposit of liber.

In order to facilitate this last operation, the old bark and wood are separated in the spring by the exudation from both of them of the glutinous slimy substance called cambium; which appears to be expressly intended, in the first instance, to facilitate the development of the subcortical tubular tissue; and, in the second place, to assist in generating the cellular tissue by which the horizontal dilatation of the axis is caused, and which maintains a communication between the bark and the centre of the stem. This communication has, by the second year, become sufficiently developed to be readily discovered, and is effected by the medullary rays spoken of in the last book. It will be remembered that there was a time when that which is now bark constituted a homogeneous body with the pith; and that it was after the leaves began to come into action that the separation which now exists between the bark and pith took place. At the time when the latter were indissolubly united they both consisted of cellular tissue, with a few spiral vessels upon the line indicative of future separation. When a deposit of wood was formed from above between them they were not wholly divided the one from the other, but the deposit was effected in such a way as to leave a communication by means of cellular tissue between the bark and the pith; and, as this formation, or medullary ray, is at all times coetaneous with that of the wood, the communication so effected between the pith and bark is quite as perfect at the end of any number of years as it was at the beginning of the first; and so it continues to the end of the growth of the plant.

The sap which is drawn from the earth into circulation by the unfolding leaves is exposed, as in the previous year, to the effect of air and light; is then returned through the petiole to the stem, and sent downwards through the bark, to be from it either conveyed to the root, or distributed horizontally by the medullary rays to the centre of the stem.

At the end of the year the same phenomena occur as took place the first season: wood is gradually deposited by slower degrees, whence the last portion is denser than the first, and gives rise to the appearance called the annual zones: the new shoot or shoots are prepared for winter, and are again elongated cones, and the original stem has acquired an increase in diameter proportioned to the quantity of new shoots which it produced, new shoots being to it now, what young leaves were to it before.

IV. The third year all that took place the year before is repeated; more roots appear; sap is again absorbed by the unfolding leaves; and its loss is made good by new fluids introduced by the roots and transmitted through the alburnum or wood of the year before; new wood and liber are formed from matter sent downwards by the buds; cambium is exuded; the horizontal development of cellular tissue is repeated, but more extensively; wood towards the end of the year is formed more slowly, and has a more compact character; and another ring appears indicative of this year's increase.

In precisely the same manner as in the second and third years of its existence will the plant continue to vegetate, till the period of its decay, each successive year being a repetition of the phenomena of that which preceded it.

V. After a certain number of years the tree arrives at the age of puberty; the period at which this occurs is very uncertain, depending in some measure upon adventitious circumstances, but more upon the idiosyncrasy, or peculiar constitution, of the individual. About the time when this alteration of habit is induced, by the influence of which the sap or blood of the plant is to be partially diverted from its former courses into channels in which its force is to be applied to the production of new individuals rather than to the extension of itself; about this time it will be remarked that certain of the young branches do not lengthen, as had been heretofore the wont of others, but assume a short stunted appearance, probably not growing two inches in the time which had been previously sufficient to produce twenty inches

of increase. Of these little stunted branches, called *spurs*, the terminal bud acquires a swollen appearance, and at length, instead of giving birth to a new shoot, produces from its bosom a cluster of twigs in the form of pedicels, each terminated by a bud, the leaves of which are modified for the purposes of reproduction, grow firmly to each other, assume peculiar forms and colours, and form a *flower*, which had been enwrapped and protected from injury during the previous winter by several layers of imperfect leaves, now brought forth as bracts. Sap is impelled into the calyx through the pedicel by gentle degrees, is taken up by it, and exposed by the surface of its tube and segments to air and light; but, having very imperfect means of returning, all that cannot be consumed by the calyx is forced onwards into the circulation of the petals, stamens, and pistil. The petals unfold themselves of a dazzling white tinged with pink, and expose the stamens; at the same time the disc changes into a saccharine substance, which is supposed to nourish the stamens and pistil, and give them energy to perform their functions.

At a fitting time, the stigmatic surface of the pistil being ready to receive the pollen, the latter is cast upon it from the anthers, which have remained near for that particular purpose. When the pollen touches the stigma, the grains adhere by means of its viscid surface, emitting a delicate membranous tube, which pierces into the stigmatic tissue, lengthens there, and conveys the matter contained in the pollen towards the ovules, which the tube finally enters by means of their foramina.

This has no sooner occurred than the petals and stamens fade and fall away, their ephemeral but important functions being accomplished. The sap which is afterwards impelled through the peduncle can only be disposed of to the calyx and ovary, where it lodges: these two swell and form a young fruit, which continues to grow as long as any new matter of growth is supplied from the parent plant. At this time the surface of the fruit performs the functions of leaves in exposing the juice to light and air; at a subsequent period it ceases to decompose carbonic acid, gains oxygen, loses its green colour, assumes the rich ruddy glow of maturity; and the

peduncle, no longer a passage for fluids, dries up and becomes unequal to supporting the fruit, which at last falls to the earth. Here, if not destroyed by animals, it lies and decays: in the succeeding spring its seeds are stimulated into life, strike root in the mass of decayed matter which surrounds them, and spring forth as new plants to undergo all the vicissitudes of their parent.

Such are the progressive phenomena in the vegetation, not only of the apple, but of all trees which are natives of northern climates, and of a large part of the herbage of the same countries, modified, of course, by peculiarities of structure and constitution; as in annual and herbaceous plants, and in those the leaves of which are opposite and not alternate: but all the more essential circumstances of their growth are the same as those of the apple tree.

If we reflect upon these phenomena, our minds can scarcely fail to be deeply impressed with admiration at the perfect simplicity and, at the same time, faultless skill, with which all the machinery is contrived upon which vegetable life depends. A few forms of tissue, interwoven horizontally and perpendicularly, constitute a stem; the development, by the first shoot that the seed produces, of buds which grow upon the same plan as the first shoot itself, and a constant repetition of the same formation, cause an increase in the length and breadth of the plant; an expansion of the bark into a leaf, within which ramify veins proceeding from the seat of nutritive matter in the new shoot, with a provision of air-passages in its substance, and of pores on its surface, enables the crude fluid sent from the root to be elaborated and digested until it becomes the peculiar secretion of the species; the contraction of a branch and its leaves forms a flower; the disintegration of the internal tissue of a petal forms pollen; the folding inwards of a leaf is sufficient to constitute a pistil; and, finally, the gorging of the pistil with fluid which it cannot part with causes the production of a fruit.

In hot latitudes there exists another race of trees, of which Palms are the representatives; and in the north there are

many herbs, in which growth by addition to the outside is wholly departed from, the reverse taking place; that is to say, their diameter increasing by addition to the inside. As the seeds of such plants are formed with only one cotyledon, they are called monocotyledonous; and their growth being from the inside, they are also named endogens. In these plants the functions of the leaves, flowers, and fruit are in nowise different from those of the apple; their peculiarity consisting only in the mode of forming their stems. When a monocotyledonous seed has vegetated, it usually does not disentangle its cotyledon from the testa, but simply protrudes the collum and the radicle; the cotyledon swelling, and remaining firmly encased in the seminal integuments. The radicle shoots downwards to become root; and a leaf is emitted from the side of the collum. This first leaf is succeeded by another half-facing it, and arising from its axil; the second produces a third half-facing it, and arising also from its axil; and, in this manner, the spiral production of leaves continues, until the plant, if caulescent, is ready to produce its stem. Up to this period, no stem having been formed, it has necessarily happened that the bases of the leaves hitherto produced have been all upon nearly the same plane: and, as each has been produced from the bosom of the other without any such intervening space as occurs in dicotyledonous plants, it would be impossible for the matter of wood, if any were formed, to be sent downwards around the circumference of the plant; it would, on the contrary, have been necessarily deposited in the centre. In point of fact, however, no deposit of wood like that of dicotyledons takes place, either now or hereafter. The union of the bases of the leaves has formed a fleshy stock, cormus, or *plate*, which, if examined, will be found to consist of a mass of cellular tissue, traversed by perpendicular and horizontal bundles of vascular and woody tissue, connected with the veins of the leaves, of which they are manifest prolongations downwards; and there is no trace of separable bark, medullary rays, or central pith: the whole body being a mass of pith, woody, and vascular tissue, mixed together.

To understand this formation yet more clearly, consider for a moment the internal structure of the petiole of a dicoty-

ledon: it is composed of a bundle or bundles of vascular tissue encased in pleurenchym, surrounded on all sides with pith, or, which is the same thing, parenchym. Now suppose a number of these petioles to be separated from their blades, and to be tied in a bunch parallel with each other, and, by lateral pressure, to be squeezed so closely together that their surfaces touch each other accurately, except at the circumference of the bunch; if a transverse section of these be made, it will exhibit the same mixture of bundles of woody tissue and parenchym, and the same absence of distinction between pith, wood, and bark, which has been noticed in the corm, or first plate, of monocotyledons.

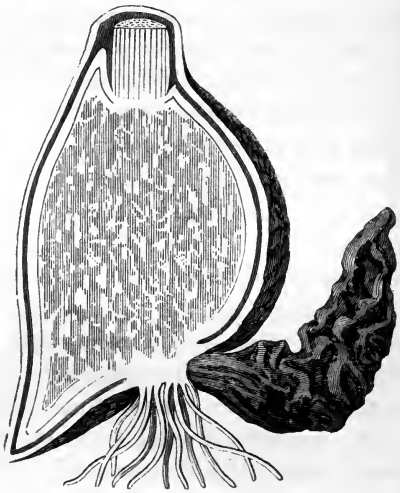
As soon as the plate has arrived at the necessary diameter, it begins to lengthen upwards, leaving at its base those leaves which were before at its circumference, and carrying upwards with it such as occupied its centre; at the same time, new leaves continue to be generated at the centre, or, as it must now be called, at the apex of the shoot.

As fresh leaves are developed, they thrust aside to the circumference those which preceded them, and a stem is by degrees produced. Since it has not been formed by additions made to its circumference by each successive leaf, it is not conical, as in dicotyledons; but, on the contrary, as its increase has been at the centre, which has no power to extend its limits, being confined by the circumference which, when once formed, does not afterwards materially alter in dimensions, it is, of necessity, cylindrical: and this is one of the marks by which a monocotyledon is often to be known, in the absence of other evidence. The centre, being but little acted upon by lateral pressure, remains loose in texture, and, until it becomes very old, does not vary much from the density acquired by it shortly after its formation; but the tissue of the circumference being continually jammed together by the pressure outwards of the new matter formed in the centre, in course of time becomes a solid mass of woody matter, the cellular tissue once intermingled with it being almost obliterated, and appearing among the bundles it formerly surrounded, like the interstices around the minute pebbles of a mosaic gem.

Such is the mode of growth of Palms, and of a great proportion of arborescent monocotyledons. But there are other monocotyledons in which this is in some measure departed from. In the common Asparagus the shoots produce a number of lateral buds, which all develope, and influence its form, as the buds of dicotyledons; so that the cylindrical figure of monocotyledons is exchanged for the conical: the internal structure remains strictly endogenous. In Grasses a similar conical figure prevails, and for the same reason; but they have this additional peculiarity, that their stem, in consequence of the great rapidity of its growth, is fistular, with transverse partitions at its nodes. The partitions are formed by the crossing of woody bundles from one side of a stem to the other; and are, perhaps, contrivances to enable the thin cylinder of the stem to resist pressure from without inwards.

In such herbaceous plants as Colchicum, the stem, after a time, is a small tuber with two buds; one at the apex, which becomes the flowering stem and leaves; the other at the base, directed downwards at an obtuse angle. Such a tuber is

fig. 190, *bis.*



multiplied by the latter bud, which pushes forward obliquely, and turning upwards, throws up a new flowering stem in the

autumn; the base of the flowering stem thickens, enlarges, and assumes the appearance of a new corm; in the spring, leaves sprout forth, and elaborate matter enough to fill the cells of the new corm with starch, and to organise another oblique bud at the base; the growth of a new individual is then accomplished. In the meanwhile, the original corm is exhausted of all its organisable contents, which are consumed in the support of the young corm produced from its base; and, by the time that the growth of the latter is completed, the mother is shrivelled up, and dies. It is easy to conceive many modifications of this.

Upon one or other of the two plans now explained are all flowering plants developed; but in flowerless plants it is different. In arborescent Ferns the stem consists of a cylinder of hard sinuous plates, connected by parenchym, and surrounding an axis, hollow, or filled up with solid matter. It would seem, in these plants, as if the stem consisted of a mere adhesion of the petioles of the leaves in a single row; and that the stem simply lengthens at the point, without transmitting woody matter downwards. Some valuable observations upon this point have been made by Mohl, who has, however, been able only to investigate the anatomical condition of Tree Fern stems, without studying their mode of growth. Lycopods equally increase by simple addition to the point; and, as this seems also to be the plan upon which development takes place in other cryptogamic plants, I have proposed the term Acrogens, to distinguish the latter from the classes of Exogens and Endogens.

When leaves are no longer formed, but growth takes place by an irregular expansion of cellular tissue in various directions, the preceding rules are departed from, and nothing being left of the vegetable fabric except the horizontal order of growth, a stem ceases to appear, and a plant becomes an unsymmetrical body, either consisting of solid masses increasing in all directions, or of filamentous matter multiplying itself by internal septation at the elongated apex.

CHAPTER II.

VITALITY.

THAT there does exist in living things a power, or system of forces, altogether independent of external agency, is undoubted. As this power is manifested so long only as life is present, ceasing with death, it is properly named VITALITY. Because it is not at variance with the laws of dynamics, or with ascertained electrical or chemical phenomena, some writers have thought themselves justified in referring it to the self-operation of ordinary physical forces. But the more the subject is studied, the more evident does it become that these forces are entirely subordinate; nor, till the WILL shall be shown to be the mere exercise of some physical power, can it be possible to deny the presence among plants, as among animals, of a mighty force controlling the material agencies of nature in obedience to the unseen commands of an action far above all human comprehension, known to us by its results alone, and called Vitality.

Were this truth but felt as it should be, physiologists would abandon that profitless, because impossible, search after first causes upon which so much time, knowledge, and skill have been expended. They would humbly admit that there are mysteries in nature which man is not permitted to read; and they would adopt for their motto, *Nec Deus absit* in exchange for the *Nec deus intersit* of the materialist.

Examples will illustrate this view better than mere argument.

An abundance of cases of the spontaneous motion of fluids in the interior of cells will be found in Book I., Chapter I., Sect. I., of this work. These motions are sometimes called electrical currents: but we know of no proof that they are electrical, and if they are, what sets the electricity in action?

The same opinion was entertained by Dutrochet as to the cause of the singular motion of green granules within the cells of Charads. But their author eventually abandoned the hypothesis.

He submitted a Chara to the influence of a large electro-magnet, capable of supporting a weight of about 4000 pounds. The stem of the plant was placed a little in front of a plane passing vertically through the poles of the horse-shoe magnet, but quite within the magnetic influence. Careful observation at the moment of establishing the electric current in the coil, proved that the speed of the circulation was unaltered. Left thus for ten minutes, all remained as before—no influence was manifested. The electric current was then suddenly reversed: the circulation exhibited no alteration. The stem was then exposed to the influence of each of the poles separately, from the base of the stem to the apex; still no change in the circulation was visible. After each experiment all magnetic influence was suppressed, but no change in the rate of the motion became evident.

It was thus shown by Dutrochet that the magnetic force, even when prodigious, exerts no influence on the circulation of Chara. Therefore he concluded that there could not be any relation between the magnetic force and the vital force producing this circulation. On the contrary, he finally admitted that the circulation is caused by a vital force, which is not electrical, since electricity merely acts like any other exciting cause, and which has no relation to the magnetic force, since the latter has not the slightest influence upon it; and he fully recognised the presence of a vital force, *sui generis*, of the nature, relations, and mechanism of which we are totally ignorant. (*Annals of Natural History*, xvii. 450.)

In some Confervas an active voluntary motion takes place among the spores in the interior of the cells; the spores strike themselves constantly against a thin part of a cell wall till, by perseverance, they rupture it and escape into the surrounding water. When there they swim about *with their small end foremost*, (see *Vegetable Kingdom*, p. 14.) These are phenomena which are clearly explicable upon no other supposition than the existence of an inherent vital force.

In like manner the pollen tubes of the grains enclosed in the pollen masses of Asclepiads are uniformly directed towards a thin place in the side of the bag which encloses them, and having pierced that place, proceed invariably to the part of the style or stigma destined to receive them,—in Morrenia overcoming great obstacles in doing so. In Armeria a plug passes down from the dome of the ovary and unerringly closes up the foramen of the ovule at the time of impregnation. In other plants the pollen tubes themselves are introduced into the foramina of the ovules with as much exactness as if they were capable of seeing where they had to pass. Such facts are inexplicable upon any known mechanical principle.

If any one of six bristles planted perpendicularly upon the leaf of Dionæa muscipula is irritated, the sides of the leaf collapse, so as to cross the ciliæ of their margin, like the teeth of a steel-trap for catching animals. And it is only by touching the bristles that the effect is produced. Roth is recorded to have seen something of the same kind in Drosera rotundifolia. If the bottom of the stamens of the common berberry is touched on the inside with the point of a needle, they spring up against the pistil. The column of the genus Stylidium, which in its quiescent position is bent over one side of the corolla, if slightly irritated, instantly springs with a jerk over to the opposite side of the flower. In Megaclinium falcatum, the labellum, which is connected very slightly with the column, is almost continually in motion; in some species of Pterostylis is observed a kind of convulsive action of the labellum. In the Appendix to the *Botanical Register* two Orchids are figured in which some most curious phenomena are observable. In the one the labellum, which is hammer-headed and placed on a long arm with a moveable elbow joint in the middle, is said to resemble an insect suspended in the air and moving with every breeze. Another singular case of spontaneous motion is that of Hedysarum gyrans. This plant has ternate leaves: the terminal leaflet, which is larger than those at the side, does not move, except to sleep; but the lateral ones, especially in warm weather, are in continual motion, both day and night, even when the terminal leaflet is asleep. External stimuli produce no effect; the motions

are very irregular; the leaflets rise or fall more or less quickly, and retain their position for uncertain periods. Cold water poured upon it stops the motion, but it is immediately renewed by warm vapour. Of a similar nature is the singular phenomenon called by Linnæus, in his figurative language, the sleep of plants. In plants with compound leaves, the leaflets fold together, while the petiole is recurved, at the approach of night; and the leaflets again expand and raise themselves at the return of day. In others the leaves converge over the flowers, as if to shelter those most delicate organs from the chill air of night. Similar phenomena have been remarked by Brignoli and Morren among the Wood-sorrels of Europe. The remarks of the latter botanist deserve to be quoted:—

"During the great heats of the month of June, when the thermometer was at + 35° (R.) in the sun, the excitability and movement of the leaves were very evident in our three indigenous species of Oxalis: Oxalis Acetosella, Oxalis stricta, and Oxalis corniculata. When the sun darts his rays in the middle of the day directly on the leaves of these plants, their three obcordate leaflets are level, horizontal, and so placed that the margins which are directed towards the point of the heart, or towards the very short partial petiole, nearly touch one another; so that then there is, so to say, no space between the leaflets. This is the position of repose. Now, if we strike the common petiole with light but repeated blows, or if we agitate by the same means the entire plant, we see, after the space of a minute,—less if it be very hot, more if it be cool,—three phenomena take place. 1. The leaflets fold themselves up along their midrib just like the moveable limb of the Dionæa muscipula, in such a manner that their two halves approach each other by their upper surface; the movement, therefore, in this case is from below upwards, and it is a folding together. 2. Each lobe of the leaflet bends inwards, so that outwardly and on its lower surface it presents a convexity more or less decided. This is a movement of incurvation. 3. Each partial petiole, although very short, bends itself from above downwards, so as to cause the leaflets to hang downwards, which then nearly touch each other by their lower surface around the common

petiole which forms the axis. This last movement is similar to that which takes place in the evening at the time of the sleep of the plant, and which has caused these leaves to be called dependent."

M. Morren offers the following explanation of the phenomenon:—

"As in all plants moveable from excitation, the organs of motion reside in the apparatus itself which moves. Now here the apparatus consists of: 1. The blade itself of the leaf, an organ of incurvation. 2. The large midrib. 3. The partial petiole; the former being an organ for folding back, the latter an organ of incurvation. Now, the blade of the leaf is composed, above, of a cuticle with pinenchymatous cells, that is to say, tabular-shaped (Meyen); beneath, of a cuticle with merenchymatous cells, swollen up, like bladders, with numerous small linear stomata between all the raised cells, so that one amongst them is often surrounded by six stomata; in the middle by a double diachyma, whose upper plane is formed of prismatic or ovoidal cells placed perpendicularly, and of such a size that upon the length of a single tabuliform cell of the upper cuticle (derme) there are six utricules of the diachyma. The plane of the diachyma is formed of ovoidal cells, placed transversely, and of such a development that two of them are equal in diameter to a merenchymatous cell of the inferior cuticle which is equal to three or four-fifths of a tabular cell of the superior cuticle. It follows from this structure that the cells of the inferior mesophyllum are double the size of those of the upper mesophyllum. The diachyma is, moreover, very rich in chlorophyllum and in round clusters of crystals, occupying the axis of the cells. It seems to me evident that analogy with the other plants which are moveable by excitation, should lead us to place the cause of the incurvation of the blade in the inferior mesophyllum, the cells of which by turgescence elongate the inferior pagina of the leaf, and thus cause the upper pagina or the mesophyllum to fold upwards. The cellular tissue is here also the essential organ of movement, and each cell a body turgescent by excitability" (*Annals of Natural History*, vol. iv.); or, as we should say, by vitality.

That it is in this sense that Professor Morren is to be understood is evident from the manner in which he endeavours to explain the singular vital actions observable in the irritable stigma of some Acanthads, &c. "The movement of the style of the Goldfussia had escaped the investigation of naturalists; it is notwithstanding very remarkable. Most of the flowers in which we see a moveable pistil possess a bilabiate stigma; here the moveable part is awl-shaped and rather spindle-shaped. The true stigma occupies only the dorsal part of the style, and when it bends back it removes as far as possible from the stamina; when it again erects itself it comes in contact with collecting hairs, which from the position of the flower, or by the help of insects, receive the pollen. The final cause of the phenomenon is very certainly the accomplishment of fecundation; but the mechanical cause is seated in the distension of the cylindrenchym of the stigma; its tissue is formed by long cylinders dilatable at one or other of the extremities, and each is filled with a liquid containing globules. These globules are excitable. They are naturally carried towards the outer extremities of the cylindrenchym, and then these extremities dilating, make the stigma bend; but when it is touched the globules and the liquid flow back to the bottom of the cylinders, and in this case, this side becoming the longest, the style erects or bends itself in a direction the reverse of that which it had before. The physiological cause resides therefore *in the excitability of a vital fluid.*"

It is indeed impossible to explain any one phenomenon of life in plants upon any other supposition. Let us take the commonest cases. The flowers of the Crocus and similar plants expand beneath the bright beams of the sun, but close as soon as they are withdrawn. The Œnotheras unfold their blossoms to the dews of evening, and wither away at the approach of day. Some Silenes roll up their petals in the day, and expand them at night. The florets of numerous Composites, and the petals of Mesembryanthemum, are erect in the absence of sun, but become reflexed when acted upon by the sun's beams; and many other such phenomena are familiar to every observer of nature. It is probable, indeed,

that a different action exists in all plants by day and night, although it is less visible in some than in others; thus plants of Corn, in which there is little indication of sleep when grown singly, exhibit that phenomenon very distinctly when observed in masses; their leaves become flaccid, and their ears droop at night. These effects have been attributed to the action of light; and it is probable that that agent contributes to produce them; for a flower removed from the shade will often expand beneath a lamp, just as it will beneath the sun itself, and De Candolle found that he could induce plants to acknowledge an artificial day and night, by alternate exposure to the light of candles. But it is obvious that there must be some cause beyond light, because many flowers will close in the afternoon while the light of the sun is still playing upon them, and the petals of others will fold up under a bright illumination, and that cause may be reasonably supposed to be an excitable vital fluid. The experiments of Macaire and Marcet prove indeed conclusively that whatever the true seat of Vegetable vitality may be, it is similar in its nature to that of the Animal Kingdom.

This has been proved by Marcet, of Geneva, who instituted a series of experiments upon the exact nature of the action of mineral and vegetable poisons. The subject of his observations was the common Kidneybean; and, in each experiment, a contrast was formed between the plant operated upon and another watered with spring water. A vessel containing two or three Bean plants, each with five or six leaves, was watered with two ounces of water, containing twelve grains of oxide of arsenic in solution. At the end of from twenty-four to thirty-six hours the plants had faded, the leaves drooped, and had even begun to turn yellow. Attempts were afterwards made to recover the plants, but without success. A branch of a Rose tree was placed in a solution of arsenic; and in twenty-four hours ten grains of water and 0·12 of a grain of arsenic had been absorbed. The branch exhibited all the symptoms of unnatural decay. In six weeks a Lilac tree was killed, in consequence of fifteen or twenty grains of moistened oxide of arsenic having been introduced into a slit in one of the branches. Mercury, under the form of corrosive sublimate,

was found to produce effects similar to those of arsenic; but no effect was produced upon a Cherry tree, by boring a hole in its stem, and introducing a few globules of liquid mercury. Tin, copper, lead, muriate of barytes, a solution of sulphuric acid, and a solution of potash, were found to be all equally destructive of vegetable life; but it was ascertained, by means of sulphate of magnesia, that those mineral substances which are innocuous to animals are harmless to vegetables also. In the experiments with vegetable poisons, the Bean plants were carefully taken from the earth, and their roots immersed in the solutions used. It had been previously ascertained, that plants so transplanted and placed in water, under ordinary circumstances, would remain in excellent health for six or eight days, and continue to vegetate as if in the earth. A plant was put into a solution of nux vomica at nine in the morning: at ten o'clock the plant seemed unhealthy; at one the petioles were all bent in the middle; and in the evening the plant was dead. Ten grains of an extract of cocculus suberosus, dissolved in two ounces of water, destroyed a Bean plant in twenty-four hours; prussic acid produced death in twelve hours, laurel water in six or seven hours, a solution of belladonna in four days, alcohol in twelve hours.

From the whole of his experiments, Marcet concluded—1st, That metallic poisons act upon vegetables nearly as they do upon animals: they appear to be absorbed and carried into different parts of a plant, altering and destroying the vessels by corrosion. 2ndly, That vegetable poisons, especially those which have been proved to destroy animals by their action upon the nervous system, also cause the death of plants: whence he infers that there exists in the latter a system of organs which is affected by poisons, nearly as the nervous system of animals.

These facts have been confirmed by others. In their experiments with gases, Turner and Christison remarked that "the phenomena, when compared with what was observed in the instances of sulphurous and hydrochloric acid, would appear to establish, in relation to vegetable life, a distinction among the poisonous gases, nearly equivalent to the difference existing between the effect of the irritant and the narcotic

poisons on animals. The gases which rank as irritants in relation to animals seem to act locally on vegetables, destroying first the parts least plentifully supplied with moisture. The narcotic gases,—including under that term those that act on the nervous system of animals,—destroy vegetable life by attacking it throughout the whole plant at once. The former, probably, act by abstracting the moisture of the leaves; the latter, by some unknown influence on their vitality. The former seem to have upon vegetables none of that sympathetic influence upon general life, which in animals follows so remarkably injuries inflicted by local irritants."

A similar result was arrived at by Macaire, whose experiments are recorded in the *Bibliothèque Universelle*, xxxi. 244., and which appear of sufficient importance to be detailed at length.

The first plant used was the Berberis vulgaris. The six stamina of the flowers of this plant have the property of rapidly approaching the pistil, when touched by the point of an instrument. The motion occurs at the base of the stamens. When cold, the motion is sometimes retarded. When put into water or solution of gum, the flowers may be preserved many days, possessing their irritability. The petals and stamens close at night to open again in the morning. Putting the stem of this plant into dilute prussic acid for four hours, occasioned the loss of the contractile property by irritation; the articulation became flexible, and might be inclined in any direction by the instrument. The leaves had scarcely begun to fade. On placing the expanded flowers on the prussic acid, the same effect took place, but much more rapidly. The experiment being repeated with an aqueous solution of opium, a similar effect was produced in nine hours.

Dilute solutions of oxide of arsenic and arseniate of potash were used: the stamens lost the power of approaching the pistil; but they were stiff, hard, withdrawn backwards, and could not have their direction altered without fracture. It seemed like an irritation, or a vegetable inflammation. Solution of corrosive sublimate more slowly produced the same effects.

Sensitive Plant (Mimosa pudica).—Experiments were now made with this vegetable. When a leaf of this plant is cut, and allowed to fall on pure water, the leaflets generally contract rapidly; but after a few moments expand, and are then susceptible of contraction by the touch of any other body. They may thus be preserved in a sensible state two or three days. If the section be made with a very sharp instrument, and without concussion, the leaves may be separated without any contraction. The branches of this plant may be preserved for several days in fresh water. Gum water also effects the same purpose.

When a cut leaf of this plant falls upon a solution of corrosive sublimate, the leaf rapidly contracts, and the leaflets curl up in an unusual manner, and do not again expand. When put into pure water, the sensibility does not return, but the whole remains stiff and immoveable. A little solution of corrosive sublimate, being put into a portion of pure water containing an expanded branch of the plant, gradually caused curling up of the leaves, which then closed and fell. If the solution be very weak, the leaves open on the morrow, and are still sensible, but ultimately contract, twist, and remain stiff till they die. Solutions of arsenic and arseniate of potash produce the same effects.

A leaf of the Sensitive Plant was in a cold diluted solution of opium: in a few moments it opened out as in water, and, after half an hour, gave the usual signs of contractibility. In six hours it was expanded, and had a natural appearance, but could not be excited to move. The leaflets were flexible at the articulations, and offered a singular contrast to the state of irritation produced by corrosive sublimate. Pure water did not recover the plant. A large branch, similarly situated, expanded its leaves; but in half an hour had lost much of its sensibility: the leaflets, though alive, seemed asleep, and required much stimulating to cause contraction. In one hour the contractions ceased: in two hours the branch was dead.

A leaf placed in prussic acid (Scheele's strength) contracted, then slightly dilated, but was quite insensible, and the articulations were flexible: water did not recover it. If

the acid be very weak, the leaflets dilate and appear to live, but are insensible. A drop of the acid placed on two leaflets of a healthy plant gradually causes contraction of the other leaflets, pair by pair. Solutions of opium and corrosive poisons have no effect when applied this way. After some time they dilate, but are insensible to external irritation: the sensibility returns in about half an hour; but the leaflets appear as if benumbed.

The plant exposed to the vapour of prussic acid is affected in the same way. Ammonia appears to favour the recovery of the plant.

A cup containing dilute prussic acid was so placed that one or two leaves, or sometimes a branch, of a healthy plant could be plunged into the liquid, or left to repose on its surface. The leaflets remained fresh and extended, but were almost immediately insensible. Being left in this state for two hours they were expanded; and no irritation could cause their contraction, though otherwise there was no appearance of an unnatural state. At five o'clock in the evening the leaves were left to themselves. At nine o'clock they were open and insensible. At midnight they were still open, whilst all the rest of the plant, and the neighbouring plants, were depressed, contracted, and in the state of sleep. On the morrow they resumed a little sensibility, but seemed benumbed.

In the same manner Macaire interfered with other plants as to the state of sleep, and found that prussic acid thoroughly deranges the botanical indications of time of Linnæus.

It is, however, conceivable that phenomena may occur among plants, having at first sight all the appearance of vital actions, but in reality produced by mere physical causes. Of this nature appears to be the catalepsy of Physostegia virginiana, described by Professor Morren.

The inflorescence of this plant is a close spike. The flowers are opposite in pairs, in a decussate manner, and are about three-quarters of the length of a calyx from each other. The phenomenon consists in this, that if you turn a flower standing in face of you so far to the right or left as to stand

over the next flower below it, it will retain its new position without springing back again to its original place; and if it is first bent to the right this will not prevent it being afterwards bent to the left; but it may be moved at pleasure to one side or the other within the limits of half the circle described by the points of the flowers round the axis on which they grow. What is called catalepsy in this plant is the power which the flowers possess of maintaining themselves in a position artificially given to them, without their elasticity bringing them back to the point from which they were turned, as is the case in all other plants.

This property is exceedingly striking when observed for the first time, and converts the Physostegia, which has tall erect stems, covered with long spikes of flowers, into a natural vane, whose corollas indicate the direction of the wind with great precision.

This cataleptic property is only preserved by the flowers when moved horizontally; if raised up and down, they spring back to their original position with considerable force. They even oscillate, in recovering their place, with great rapidity, which shows that their stalks are, at least in a vertical direction, provided with a high degree of irritability. Similar results are obtained from moving the flowers in all other directions except the horizontal, to which the cataleptic effect is confined. It is moreover exceedingly remarkable that the effect should be limited to the period of flowering; neither before that time, when the flower-buds are pressed upon by their bracts, nor afterwards when the pedicels are directed obliquely upwards, is the phenomenon observable; so that it appears evident that this catalepsy is limited to the time of fertilisation; it favours the projection of pollen upon the stigma by the shocks communicated to the corolla by the wind, in displacing it, and striking it against other flowers; and M. Morren regards it as one of the numerous physiological efforts which are manifested in such infinite variety at the time of fertilisation.

M. De Candolle, who has noticed this phenomenon, ascribes it, with some doubt, to the "low degree of elasticity resident in the flower-stalk," (*Physiologie Végétale*, i. 14); M. Morren's

researches have led him to a very different conclusion. He found that the non-elasticity of the flower-stalk, when moved horizontally, exists only so long as it adheres to the stem, and that when it is cut off it indicates abundant elasticity in all directions; and the eventual result of his inquiries was, that, after all, the catalepsy of this plant is only sham. I now quote the author literally. "In fact, if the flower-stalk is elastic when cut off, why should it be cataleptic while adhering to the stem? I therefore removed from a stem, with very sharp scissors, a bract quite down to its base; I then turned the flower to the right, when it sprang back to the left, and *vice versâ;* so that under these circumstances the elasticity was restored, and the catalepsy gone. This curious experiment, the precise and positive result of which was really surprising, always succeeded; and if an observer were not to push his inquiries any further, he would conclude that the phenomenon is dependent upon the bracts; it will be seen that in point of fact there is no catalepsy at all.

Other experiments showed that by cutting away half a bract, dividing it from the point to the base through the midrib, the flower recovered its elasticity on the side whence the bract was removed, but remained destitute of it on the side where the bract was uninjured; so that by such a contrivance a flower can be brought into a state of elasticity on one side, and of catalepsy on the other! It is, however, necessary to cut away the bract down to the point of its insertion, otherwise the apparent catalepsy is not destroyed.

M. Morren observes that these curious phenomena are wholly dependent upon the peculiar arrangement and proportion of the flower-stalks and bracts, and that they are merely mechanical. It appears that each pedicel reposes in a bract channelled like a gutter, and that its length is a trifle more than half the breadth of the bract at its base, and it is in this circumstance that the whole secret lies. The bract is much more rigid than the flower-stalk, is immoveable, and is placed close to the flower; when the flower is turned to one side, the base of the calyx, which forms a projection above the flower-stalk, slips over the edge of the bract, catches there, and the force

of the flower-stalk being less than the resistance of the bract, it cannot be pulled back again by any power of its own. After flowering, the flower-stalk becomes more woody and stronger, and this is able to recover itself if it catches against the edge of the bract, which is, however, not likely to happen, because it is raised upwards beyond contact with that organ.

In conclusion, M. Morren compares the mechanism which causes the apparent catalepsy of Physostegia to the escapement of a watch, where a hooked lever stops the wheel, and regulates the movements.

To mere mechanical action ought also, perhaps, to be referred the curious phenomenon well known to exist in the fruit of the Elaterium, or Spirting Cucumber. In this plant the peduncle, at a certain period, when the fruit has attained its perfect maturity, is expelled, along with the seeds and the mucus that surrounds them, with very considerable violence. Here, however, endosmose appears to offer a satisfactory explanation. According to Dutrochet, the fluid of the placentary matter in this fruit gradually acquires a greater density than that which surrounds it, and begins to empty the tissue of the pericarpium: as the fruit increases in size the same operation continues to take place; the pulpy matter in the centre is constantly augmenting in volume at the expense of the pericarpium; but, so long as growth goes on, the addition of new tissue, or the distension of old, corresponds with the increase of volume of the centre. At last growth ceases, but endosmose proceeds; and then the tissue that lines the walls of the central cell is pressed upon forcibly by the pulp that it encloses, until this pressure becomes so violent that rupture must take place somewhere. The peduncle, being articulated with the fruit, at length gives way, and is expelled with violence; at the same time the cellules of tissue lining the cavity all simultaneously recover their form, the pressure upon them being removed, and instantly contract the space occupied by the mucous pulp; the consequence of which is that it also is forced outwards at the same time as the peduncle. It has been found by

measurement, that the diameter of the central cavity is less after the bursting of the fruit than before.

The valves of Impatiens noli-tangere, when the fruit is ripe, separate and spring back with great elasticity when touched. In this case the phenomenon is apparently capable of explanation upon a similar principle to the Elaterium. In the fruit of Impatiens, the tissue of the valves consists of cellules that gradually diminish in size from the outside to the inside; and the fluids of the external cellules are the densest. The latter gradually empty the inner cellules and distend themselves; so that the external tissue is disposed to expand, and the internal to contract, whenever anything occurs to destroy the force that keeps them straight. This at last happens by the disarticulation of the valves, the peduncle, and the axis; and then each valve rapidly rolls inwards with a sudden spontaneous movement. Dutrochet proved that it was possible to invert this phenomenon by producing exosmose: for that purpose he threw fresh valves of Impatiens into sugar and water, which gradually emptied the external tissue, and, after rendering the valves straight, at length curved them backwards.

In Kalmia the anthers are retained in little niches of the corolla; and, as soon as they are by any cause extricated, the filaments which had been curved back recover themselves with a spring. In certain orchids, of the tribe called Vandeæ, the caudicula to which the pollen masses are attached will often, upon the removal of the anther, disengage itself with a sudden jerk, like a spring from which the pressure is removed.

For numerous observations upon other cases of vegetable irritability, see Dutrochet's *Mémoires* previously quoted, in which there is much speculation upon the subject.

In conclusion, mere hygrometrical action must be mentioned as the cause of some phenomena wholly independent of vital action. Dr. Lankester thus describes them in Funaria hygrometrica. "If one of the dried setæ be taken in the hand, and its lower portion moistened with the finger, the capsule will be seen to turn from right to left, making two, three, or even more complete revolutions; if now the

upper portion be moistened in like manner, the capsule will turn round more rapidly in a contrary direction. This phenomenon is exhibited whichever portion of the seta is first wetted. If both ends are moistened at the same time, a tremulous wavering is observed without any motion, but in a few seconds the capsule begins to move in one direction or the other. The direction in this instance is in some measure determined by the quantity of moisture applied, but the upper part seems most easily affected, and the motion arising from moistening it is much more rapid than from the lower portion. If the capsule is held in the fingers the lower end presents the same motions. If both ends are held and the middle left free and moisture is applied, there is an evident effort made to curl the whole stem, but this is not effected. On observing these curious phenomena, I was induced to submit the setæ to an examination by the microscope, and their structure explains in some measure the nature of the motions observed. The entire seta is composed of an elongated cellular tissue which is arranged in a spiral manner. The tissue is not, however, continued in the same direction through the whole length of the seta, but at about two thirds of its length it begins to straighten, and at length in the upper part runs spirally in an opposite direction to that of the lower portion, the fibres forming a much more acute angle in the upper, than the lower part of their course. This structure is most apparent in the dried setæ. In the young state the fibres are quite straight; as they increase in age they become more spiral; and in the green setæ, just before the capsule is ripened, the spiral fibres with their double direction are quite evident. The immediate cause of the motions appears to be the absorption of moisture by the elongated spiral tissue. Whether the moisture admitted into the tissue straightens it by the force with which the fluid passes along the bent tubes, or whether it arises from the mere distension of the external tissue, may be a question. The capsule turns round in a direction contrary to that of the spiral of each end, and after the seta has been moistened and has turned round in both directions, its length is greater than it was previously. The more rapid movements of the

capsule when the upper end is wetted is accounted for by the circumstance of the upper end of the seta being more twisted than the lower end. It does not, however, appear that the mere spiral form of the fibres is the cause of the motion, as this structure exists in the green setæ, which are entirely insusceptible of motion from the application of moisture. Nor is merely the dryness of the fibres the cause, as the green setæ, though thoroughly dried, do not exhibit any movement. But at the period of ripening the capsule is found bent towards the surface of the earth, and although I have not observed it turning round, I think it is probable that during this period a further twisting of the whole seta takes place, this direction being given by the already spiral form of the fibres, and constituting the true cause of the motions observed. This is rendered more probable by the fact that the spiral form of the tissue exists even after it has been macerated in water." (*Annals of Natural History*, vol. iv. p. 361.)

These views entirely correspond with those of M. Gaudichaud, as will appear from the following extract from his Observations on Physiological Chemistry :—

" Ainsi donc nous proposerions, pour obvier aux inconvénients qui résultent de la confusion des noms et des idées, d'admettre trois sortes de chimie :

" 1°. La chimie des corps inorganiques, qui n'a pas besoin d'être caractérisée ;

" 2°. La chimie des corps organisés, qui est aujourd'hui si riche en faits admirables, mais qui n'en est pas moins désorganisatrice pour cela ;

" 3°. La chimie physiologique ou naturelle, qui, sous l'action d'une force encore inconnue, sous l'action de la vie, est essentiellement organisatrice, et dont le sublime artisan, les laboratoires, les appareils, les agents, les forces et les combinaisons n'ont rien de commun avec ceux des autres chimies.

" C'est donc vers cette chimie qu'on ne connaît pas encore, et dont on parle toujours, qu'il faut diriger tous nos efforts, si nous voulons marcher dans la route de la vérité, et tenter d'arriver un jour à la connaissance des causes

appréciables de la vie ou, autrement dit, de la seule et véritable physiologie végétale.

"Nous n'avons, pour cela, qu'un seul moyen à employer: c'est de faire en phytologie ce qu'on a pratiqué en zoologie; c'est d'étudier à fond l'organisation des êtres végétaux avant de chercher à en expliquer les fonctions; c'est de faire des anatomies générales, et, en un mot, d'arriver à mieux connaître les merveilleux appareils où s'accomplissent les phénomenes de la vie."

CHAPTER III.

OF THE CHEMICAL CONSTITUTION OF THE ELEMENTARY ORGANS.

THE tissue of plants, as it is first generated, and before it is incrusted with the peculiar secretions formed by the leaves, consists exclusively of oxygen, hydrogen, and carbon: and it is probable that none of the kinds of tissue differ originally in their proportions of these three principles; for the microscope does not show a difference in the action of chemical agents upon them.

I mention this because Mr. Rigg has arrived at a different conclusion, the accuracy of which has been insisted upon by the Rev. J. B. Reade, in a paper printed in *Taylor's Magazine* (Nov. 1837). It must be, however, apparent to any person conversant with vegetable anatomy, that such a separation of tissue as in Mr. Rigg's case is supposed to have been obtained is physically impossible, and, consequently, the results given are fallacious.

The subject has been subsequently taken up by Schleiden and Payen, whose experiments, made independently of each other, and in entirely different ways, both lead to the conclusion that the original tissue of plants is in all cases of the same chemical constitution, or nearly so, but that the sedimentary deposit, whether sclerogen, or other matter, formed inside each sac of tissue is of some other chemical nature; the lignine of chemists is therefore composed of two or more different substances, viz. the primitive tissue and its subsequent incrustations. As this subject is important with reference to many phenomena in vegetable physiology, I give at some length the results of both Schleiden and Payen.

The former makes a statement in *Wiegman's Archives* to the following effect:—

"In the manuals which treat of organic chemistry, we generally find woody fibre treated of as a proximate element amongst the indifferent vegetable substances, along with starch, gum, sugar, &c. It is only lately that Reade has endeavoured to earn the merit of analysing the different forms of organised vegetable substances when separated, but I doubt whether anything available for science has resulted therefrom. I will, however, in no wise intimate that Mr. Reade has not made use of really isolated spiral vessels in his analysis, since he expressly asserts it; but he does not once mention the remotest attempt to separate the interior matter from the cells and vessels, which necessarily must have been done if any value were to be attached to the result of the elementary analysis.

"This question arises with every one who knows that the greater part of vegetable tissue consists of a pellucid membrane, and the formations deposited on its inner surface: Are this membrane and the subsequent deposits formed of the same chemical substance? In fact, as we know from Mohl and Meyen that the increased thickness of the walls of cells consists of several layers, that even the spiral fibres are composed of an original fibre, and a subsequently deposited covering surrounding it, which I have found confirmed in innumerable instances, the further question arises whether both the single layers of incrustation, and the (additional?) parts of the spiral fibres, are not different from each other. As there can be no mechanical separation of such closely combined and microscopic parts, nothing can be done further than to superadd to chemical examination the use of the microscope, and by this means to observe the action of chemical reagents on the different elementary parts of the vegetable structure.

"I. I had made fine sections of an internodium of Arundo Donax an inch in diameter, and boiled them for some minutes in a solution of caustic potash. On bringing the section again under the microscope I was surprised by a peculiar appearance. A few ringed and spiral vessels were cut through, so that one could plainly see the section of their very thick fibre. By the boiling in caustic potash the spiral

vessel was acted upon in its different parts in a very peculiar manner. The exterior enveloping membrane (the original wall of the cell) was apparently not in the slightest degree altered; it was still firm, close, transparent, and clear as water. The fibre itself consisted of two component parts; namely, of a (primary?) fibre lying close to the wall of the cell, and of an enveloping membrane surrounding the fibre on the three free sides in the interior of the cell. The caustic potash had coloured this enveloping membrane of a somewhat darker yellow, otherwise it was firm and apparently unaltered; the primary fibre, on the contrary, was changed into a gelatinous mass, so that on the plane of the section it was swelled up into a pretty considerable elevation. Unfortunately I did not follow up or vary these interesting observations, till after I had thrown away the remainder of the fresh piece of the Donax.

"II. The next experiment I instituted was on the leaves of Pleurothallis ruscifolia. The greater part of the cells of this plant contain beautiful spiral fibres, which appear to grow firmly against the walls of the cells. These fibres are all very broad and flat, like a riband, their thickness varying according to their position. Those cells which are situated vertically, immediately under the epidermis of the under side of the leaf, contain a thicker fibre than the less regularly formed cells, which are separated from the latter by a layer of green parenchyma, and from the upper epidermis of the leaf by an occasionally broken layer of colourless cells, mostly with plain walls. After I had boiled fine sections of this leaf in caustic potash for a few minutes, and again examined them, I found that the spires of the first-mentioned layer had become entirely separated from the walls of the cells. Under the simple microscope I could easily tear up single cells with a needle, and isolate the whole spiral fibre uninjured. Moreover, all the fibres were tumefied, and had acquired a gelatinous appearance from the action of the caustic potash. I now added a drop of sulphuric acid, which neutralised the potash with effervescence, and I then added an alcoholic solution of iodine. On again bringing the object under the microscope I was most agreeably surprised. All the spiral fibres, according to the varying thickness of the section (hence

the unequal action of the caustic potash), appeared of different shades, from claret colour to the deepest violet. In those places where the section was not more than a single cell in thickness, a difference between the fibres in the above mentioned layers was visible, inasmuch as those of the under side of the leaf (the thickest), even where they were most deeply coloured, did not appear of a pure violet colour, but redder, somewhat as if there had been a slight addition of orange. These fibres were also evidently less tumid, and the boundaries were more clearly defined. Those in the middle of the leaf, on the contrary, appeared quite gelatinous, and were coloured of a light blue. The membrane of the cells was in all cases clear as water, and colourless. This was not all: those cells which contained no spiral fibres, and which before, when magnified 230 times, appeared to consist of quite simple walls, even those of the green parenchyma, appeared now completely pitted; the primitive membrane and its pits were clear as water, and colourless, whilst the pits of the thickening layer were of a violet colour.

"III. I now took for comparison a woody stalk of Rosmarinus officinalis, and treated it in precisely the same manner. The result differed slightly from the above. The cells of the pith are here very thick-sided and pitted, as are also the exterior cells. The wood consists of the medullary sheath, of spiral vessels, and of prosenchymatous cells, the walls of which are just like the woody cells of very young coniferous wood. Here, in every part except the youngest annual rings, the original membrane (even of the spiral vessels) was not coloured, whilst those parts superposed, and even the spiral fibres, were deep orange. The cells of the youngest annual ring, on the contrary, appeared slightly pitted and very pale blue.

"IV. A species of Pelargonium, when submitted to the same action, gave the same results, only that the thin-walled but pitted exterior cells were also coloured blue.

"V. In the Teltow Turnip and Carrot, the primitive walls of the cells remained colourless; the incrusting layers of the same became blue; whilst, on the contrary, the fibres of the spiral and reticulated vessels became deep orange.

"VI. The spiral fibres, in the cells of a leaf of Oncidium

altissimum, which had been preserved for seven months in weak alcohol (of about 30°), were coloured orange. The spires here consist, however, of two parts, which on the plane of the section could be easily distinguished, as in Arundo Donax; and I imagine that the spire in Pleurothallis consists only of the inner original fibre. I was not able to institute any experiments with fresh leaves of this plant, and have therefore not been able to decide this question with certainty. The original cellular membrane remained here, as in the first-mentioned cases, colourless, and the layers of increase became blue.

"VII. Opuntia monacantha gave the same results. In all the cells which were completely converted into wood, the additional layers, whether spiral or pitted, became of a deep orange colour, those of the pith and bark blue, and the primary cellular membrane still remained clear as water.

"An Echinocactus gave the same result.

"VIII. The wood of Betula alba and Populus tremula, when submitted to the above manipulation, showed nothing but pitted formations, the primitive membrane of which remained colourless, whilst the layers of increase were coloured dark orange.

"IX. A five years' old shoot of the trunk of Pinus silvestris gave, as regards the original walls of the cells, confirmation of the former constant results. The layers of increase were coloured orange, the cells of the bark and the youngest annual rings light blue.

"It is of course to be understood, that, by comparative experiments on all these plants, I had previously satisfied myself of the absence of starch in the cells in question.

"The foregoing, though only preliminary experiments, seem to indicate the following results:—

"1. Vegetable tissue consists of three distinct chemical substances:—

a. The original membrane of the cells.

b. The primary layers upon this.

c. The secondary layers.

"2. The first substance (1. *a*.) undergoes no apparent change by a short boiling in caustic potash.

"3. The second (1. *b*.) by short boiling in the caustic alkali

is converted into starch, carbonic acid being evolved (granting that starch is the only substance upon which iodine acts so characteristically).

"4. The third (1. *c.*) by boiling in caustic potash is converted into a peculiar, as yet unknown (?), vegetable principle, which is coloured orange yellow by iodine. Whether in this case carbonic acid be also formed, I will not take upon myself to decide; at least in Experiment VIII., on the addition of sulphuric acid, I did not observe any effervescence. Moreover, this orange colour is as distant as heaven from earth, from the colour produced by adding iodine to vegetable mucus.

"Whether the carbonic acid be formed at the expense of the carbon of the vegetable substance uniting with the oxygen of the air, or by the decomposition of the water, remains still to be investigated; as, likewise, to discover whether by longer boiling, it could take up more carbon, and become converted into oxalic acid.

"The most interesting result is, however, without doubt, that, by the action of the caustic potash, one portion of vegetable matter becomes, by a retrograde metamorphosis, as it were, again converted into starch; a discovery, the extension of which gives promise of most interesting results for organic chemistry."

In another place Schleiden gives the following general summary of the chemical condition of vegetable substances: —"The vegetable substances, usually called indifferent, and which belong to the starch series, form but a small part of the infinitely varied materials which occur in plants. Plants form during their vegetation an elementary chemical matter (no allusion is here meant to the old notions of primitive mucus), which has the same elementary composition in all stages of vegetation; but is capable of infinite modifications, owing to imperceptible internal changes, and especially to the increase and diminution of the water in combination with it. These modifications depend, however, not merely on the number of atoms of water but also on the combinations of different elements, and at present seem to form a continuous series, the contiguous members of which do not

appear to differ materially. The lowest of this series Schleiden regards as sugar, the highest as the perfect cell-membrane. The members of this supposed series are described as becoming more and more insoluble in water as they ascend the scale."

M. Payen selected with the utmost care the nascent tissue of the ovules of the Almond, Apple, and Sunflower; the half-formed tissue of the Cucumber; the sap of the same plant; the two months' old pith of the Elder; the pith of Æschynomene paludosa; the hairs of Cotton; and the new tissue of spongioles. They gave him the following results:—

	Almond.	Apple.	Sunflower.	Sap of Cucumber.	Tissue of Cucumber.	Elder.	Average of Æschynomene.	Average of Cotton.	Spongioles.
Carbon .	43·57	44·7	44·1	43·9	43·8	43·37	43·31	44·67	43·
Hydrogen	6·11	6·	6·2	6·22	6·11	6·04	6·9	5·68	6·18
Oxygen .	50·32	49·3	49·7	49·88	50·1	50·59	50·1	49·3	50·82

But when he came to analyse wood in which a deposit had taken place, he found these proportions materially altered; the numbers being

	Oak.	Beech.	Herminiera.
Carbon	54·44	54·35	47·18
Hydrogen	6·24	6·25	5·94
Oxygen	39·32	39·5	46·88

When, however, the tissue was acted upon by such agents as have the property of destroying the matter of lignification, the proportions of the three fundamental principles approached more nearly those of primitive tissue.

	Oak treated with Soda.	Beech treated with Soda.	Aspen.		Oak and Beech treated in concentrated Nitric Acid, and afterwards washed with Soda.
			Washed once with Soda.	Washed twice with Soda.	
Carbon . .	49·68	49·4	48·	47·71	43·85
Hydrogen .	6·02	6·13	6·4	6·42	5·86
Oxygen . .	44·30	44·47	45·56	45·87	50·28

With reference to the discrepancy between the first and last of these tables, Payen remarks, that, as alkalies do not remove all the matter of lignification, it is possible that this substance may consist of two kinds of matter, one of which only is capable of being acted upon by azotic acid. He also adds that, although concentrated sulphuric acid has the same power as nitric acid of separating from the primitive tissue of plants their sedimentary matter, yet it possesses this difference, that it gives it the property of becoming blue when acted upon by iodine; a circumstance which has doubtless given rise to the statement that lignine may be transformed into starch. (*Comptes rendus*, vii. 1055. 1125.)

M. Payen, in a second memoir upon this subject, names the unchanged primitive tissue of plants *cellulose*, and says it has the same composition as starch; the matter of lignification he regards as the true lignine of chemists. (*Comptes rendus*, viii. 52.) His analyses of cellulose lie between 43 and 45 of carbon in 100; 6·04 and 6·32 hydrogen; and 48·55 and 50·59 oxygen, which may be represented by the formulæ $C_{24} H_{18} O_9 + H_2 O$, or $C_{24} H_{20} O_{10}$. Leaves cleaned of a waxy incrusting substance, yielded cellular matter of the same composition. Spiral vessels of the Musa merely cleaned of their incrusting substance, by ammonia, water, weak muriatic acid, &c., yielded 0·484 carbon; but on being treated with heated potash, only 0·44 carbon. Uncontaminated membrane from the grain of wheat had the same constitution as other plants. The cells in the circumference of the grain exhibited a grey colour, which was caused by a gelatinous substance that covers their membrane. The application of tannin coloured and contracted this substance, ammonia and acetic acid dissolved it, and left the pure membrane behind; a solution of iodine coloured the gelatinous substance yellow, the starch dark violet, and left the simple membrane uncoloured. Vegetable remains, from cow-dung, after having been digested, had the before-mentioned composition. The hair of the seed of the Virginian Poplar Tree behaved in the same manner as cotton. It was difficult to separate firwood from all foreign substances; the cellulose, however, after this was accomplished,

exhibited its usual composition. A similar examination was made of the purified membrane of other plants, and always with the same result, showing that cellulose itself is uniform in its composition, and that all seeming variations in it are owing to the presence of azotised matter of various kinds, deposited on the surface of the membrane, and not penetrating into its interior.

CHAPTER IV.

OF THE ELEMENTARY ORGANS.

THE general properties of the elementary organs are, *elasticity, extensibility, contractibility,* and *permeability* to fluids or gaseous matter. The first gives plants the power of bending to the breeze, and of swaying backwards and forwards without breaking. The second enables them to develope with great rapidity when it is necessary for them to do so, and also to give way to pressure without tearing. The third causes parts that have been overstrained to recover their natural dimensions when the straining power is removed, and permits the mouths of wounded vessels to close up so as to prevent the loss of their contents. The fourth secures the free communication of the fluids through every part of a plant which is not choked up with earthy matter.

The special properties of the elementary organs must be considered separately.

That of these the CELLULAR TISSUE is the most important is apparent by its being the only one of the elementary organs which is uniformly present in plants; and by its being the chief constituent of all those compound organs which are most essential to the preservation of species.

It transmits fluids in all directions. In most cellular plants no other tissue exists, and yet in them a circulation of sap takes place. No other tissue is found in the embryo, through which, nevertheless, fluids pass freely; the spongioles, and all other absorbents consist of nothing else; it constitutes the whole of the medullary rays, conveying the elaborated juices from the bark towards the centre of the stem; all the parenchyma in which the sap is diffused upon entering the leaf, and by which it is exposed to evaporation, light, and atmospheric action, consists of cellular tissue; much of the

bark in which the descending current of the sap takes place is also composed of it; and in endogenous plants, there appears to be no other lateral route that the sap can take, than through the cellular substance in which the vascular system is embedded. It must, therefore, be readily permeable to fluids although it has no visible pores.

In all cases of wounds, or even of the development of new parts, cellular tissue *is first generated:* for example, the granulations that form at the extremity of a cutting when embedded in earth, or on the lips of incisions in the wood or bark; the extremities of young roots; scales, which are generally the commencement of leaves; the growing point; pith, which is the first part created, when the stem shoots up; nascent stamens and pistils; ovules; and, finally, many rudimentary parts: in all these at first, or constantly, is found cellular tissue alone.

It is that from which leaf-buds are generated. These organs always appear from some part of the medullary system; when adventitious, from the ends of the medullary rays if developed by stems, or from the parenchym if appearing upon leaves.

It may be considered *the flesh of vegetable bodies.* The matter which surrounds and keeps in their place all the ramifications or divisions of the vascular system is cellular tissue. In it the plates of wood of exogenous plants, the woody bundles of endogenous plants, the veins of leaves, and, indeed, the whole of the central system of all of them, are either embedded or inclosed.

The action of fertilisation appears to take place exclusively through its agency. Pollen is only cellular tissue in a particular state; the coats of the anther are composed entirely of it; and the tissue of the stigma, through which fertilisation is conveyed to the ovules, is merely a modification of the cellular. The ovules themselves, with their sacs, at the time they receive the vivifying influence, are a semitransparent congeries of cells.

It is, finally, *the tissue in which amylaceous or saccharine secretions are deposited.* These occur chiefly in roots, as in the Cyclamen and Beet; in tubers, as in the Potato and

Arrow-root; in rhizomes, as in the Ginger; in soft stems, such as those of the Sago-Palm and Sugar-cane; in albumen, as that of Corn; in pith, as in the Cassava; in the disk of the flower, as in Amygdalus; and, finally, in the bark, as in all exogenous plants; and cellular tissue is the principal, or exclusive, constituent of these parts.

In the form of articulated BOTHRENCHYM, when collected together into hollow cylinders, it serves for the rapid transmission of fluids in the direction of the stem; and it is well worth notice, that the size of the tubes of articulated bothrenchym, and their abundance, are usually in proportion to the length to which fluid has to be conveyed. Thus in the Vine, Phytocrene, the common Cane, and such plants, the pitted tissue is unusually large and abundant; in ordinary trees much less so; and in herbaceous plants it hardly exists. Bothrenchym eventually ceases to convey fluid, and becomes filled with air. The use of other kinds of bothrenchym is not known.

PLEURENCHYM is apparently destined for the conveyance of fluid upwards or downwards, from one end of a body to another, and for giving firmness and elasticity to every part.

That it is intended *for the conveyance of fluid* in particular channels seems to be proved: 1. from its constituting the principal part of all wood, particularly of that which is formed in stems the last in each year, and in which fluid first ascends in the ensuing season; 2. from its presence in the veins of leaves where a rapid circulation is known to take place, forming in those plants both the adducent and reducent channels of the sap; and, 3., from its passing downwards from the leaves into the bark, thus forming a passage through which the peculiar secretions may, when elaborated, arrive at the stations where they are finally to be deposited. Knight is clearly of opinion that it conveys fluid either upwards or downwards; in which I fully concur with him: the power of cuttings to grow when inverted seems, indeed, a conclusive proof of this. Dutrochet, however, endeavours to prove that it merely serves for a downward conveyance.

With regard *to its giving firmness and elasticity to every part*, we need only consider its surprising tenacity, as evinced in hemp, flax, and the like; and its constantly surrounding and protecting the ramifications of the vascular system, which has no firmness or tenacity itself. To this evidence might be added, the admirable manner in which it is contrived to answer such an end. It consists, as has been seen, of lignified slender tubes, each of which is indeed possessed of but a slight degree of strength; but being of different lengths, tapering to each extremity, and overlapping each other in various degrees, these are consolidated into a mass which considerable force is insufficient to break. Any one who will examine a single thread of the finest flax, with a microscope which magnifies only 180 times, will find that what to the eye appears a single thread is in reality composed of a great number of distinct tubes.

It is also the tissue from which roots are emitted. Unlike the leaf-buds, roots are always prolongations of the woody tissue of the stem, as may be seen by tracing a young root to its origin. The woody tissue, when applied to this purpose, is, however, always covered with cellular tissue.

The real nature of the functions of the VASCULAR SYSTEM has been the subject of great difference of opinion. *Spiral vessels* have been most commonly supposed to be destined for the conveyance of air; and it seems difficult to conceive how any one accustomed to anatomical observations, and who has remarked their dark appearance when lying in water, can doubt that fact. Nevertheless, many observers, and among them Dutrochet, assert that they serve for the transmission of fluids upwards from the roots. This physiologist states that, if the end of a branch be immersed in coloured fluid, the latter will ascend in both the spiral vessels and articulated bothrenchym; but that in the former it will only rise up to the level of the fluid in which the branch is immersed, while through the latter it will travel into the extremities of the branches. But from this statement it does not appear that spiral vessels convey fluid; it only shows that M. Dutrochet confounds one kind of tissue with another, when he infers

that spiral vessels perform certain functions, because such functions are proper to bothrenchym in a particular state. It has also been asked, how the opinion that spiral vessels are the sap-vessels is to be reconciled with the fact of their non-existence in multitudes of plants in which the sap circulates freely. To which might have been, or perhaps has been, added the question, why they do not exist in the wood, where a movement of sap chiefly takes place in exogenous trees. And further, it has always been remarked, that, if a transverse section of a Vine, for instance, or any other plant, be put under water, bubbles of air rise through the water from the mouths of the spiral vessels of the medullary sheath. But then, it has been urged, that coloured fluids manifestly rise in the spiral vessels; a statement which has been admitted when the spiral vessels are wounded at the part plunged in the colouring fluid, but denied in other circumstances. Indeed, to persons acquainted with the difficulty of microscopic investigations, the obscurity that practically surrounds a question of this sort must be apparent enough.

Kützing, adopting the views of Schulthess and Oken, has recently asserted that the spiral vessels represent the nervous system of plants; and that both they and the tubes of pleurenchym perform the same office in the system of vegetable vitality, as metallic wires in conducting electromagnetical currents. (*Linnæa*, xii. 26. Schulthess, *Drei Vorlesungen über Electromagnetismus, gehalten in der naturforschenden Gesellschaft zu Zurich:* 1835.)

The use of spiral vessels has been investigated with care by Bischoff, who instituted some delicate and ingenious experiments, for the purpose of determining the real contents and office of the spiral vessels. It is impossible to find room here for a detailed account of his experiments, for which the reader is referred to his thesis *De vera Vasorum Plantarum Spiralium Structura et Functione Commentatio:* Bonn, 1829. It must be sufficient to state, that, by accurate chemical tests, by a careful purification of the water employed from all presence of air, and by separating bundles of the spiral vessels of the Gourd (Cucurbita Pepo), and of some other plants from the accompanying cellular substance, he came to the following

conclusions, which, if not exactly, are probably substantially correct:—"That plants, like all other living bodies, require, for the support of their vital functions, a free communication with air; and that it is more especially oxygen which when absorbed by the roots from the soil, renders the crude fluid fit for the nourishment and support of a plant, just as blood is rendered fit for that of animals. But, for this purpose, it is not sufficient that the external surface should be surrounded by the atmosphere; other aëriferous organs are provided, in the form of spiral vessels, which are placed internally, and convey air containing an unusual proportion of oxygen, which is obtained through the root, by their own vital force, from the earth and water. In a hundred parts of this air twenty-seven to thirty parts are of oxygen, which is in part lost during the day by the surface of plants under the direct influence of the solar rays."

With such evidence of the aëriferous functions of the spiral vessels, it will doubtless to many appear probable that this question is settled, as far as spiral vessels, properly so called, are concerned. Whether or not *ducts* have a different function is uncertain; it is probable, however, from the extreme thinness of their sides, that they are really filled with fluid when full grown, whatever may have been the case when they were first generated.

Link, who formerly considered trachenchym a part of the aëriferous system, afterwards declared its function to be that of conveying nutritious secretions. (*Element.* ed. 2. i. 188.) He considered that opinion proved by certain plants which he had grown in a solution of prussiate of potash, having had their spiral vessels stained blue when afterwards grown in sulphate of iron.

In his most recent writings he speaks of the question as follows:—"It has always been a question, whether the spiral vessels are air tubes, or whether they carry the juices for nutrition? I myself have twice changed my opinion regarding it, because it was more my object to arrive at the truth than to insist upon being right. Dr. Schleiden despatches the question very quickly. He says, 'I found, almost without exception, in all Cactaceæ, that the vessels, as they issued

from the cambium, were filled with air. Indeed, I must confess, that I cannot conceive how any one, who has examined a great number of plants with attention, and only applies sound logic, can set up the doctrine, that the spiral vessels, and the woody fibres associated with them, are intended to carry fluid. Never and nowhere is a fluid found in them, excepting during a short time in the spring, in the forest trees of our own climate, which may be accounted for very simply, by the superabundance of the rising sap, and the permeability of the cell-membrane; but this being only a periodical phenomenon, belongs as little to the usual course of vegetation, as the human uterus can be said to be a blood-vessel on account of its menstruating. A considerable quantity of fluid flows out rapidly from the cut stem of the Hoya carnosa in our hothouses, but the microscope instantly shows, that all the spiral and porous vessels carry only air. The answer derived from the rapidity of the flowing out of sap is not worth much; for every botanist knows, or may readily convince himself, by placing a slice of potato under the microscope, and adding a drop of tincture of iodine, when it progresses as rapidly through the walls of the cell as on the table; therefore the living membrane of the cell offers little or no resistance to the absorption of fluids. In the same way as inorganic substances are permeable (most of the perfect crystals, at least of the alkalies and earths) to the imponderables, light, warmth, &c., so also is the organic substance permeable for fluids. It is not the passing through of a fluid, which is the effect of a vital power, which requires explanation, but quite the reverse; it is the retention of the fluids in certain cells, which retention either originates from a particular organisation, as in the epidermis, or from the difference of the medium on both surfaces (air and fluid), as, for instance, in the air cells, or from peculiar organic powers, as, for instance, in the cells with coloured juices, existing between the cells with uncoloured juices. Since the lifeless vegetable membrane retains fluids, the most simple method is to attribute this as a primary quality also to the living membranes, and to search only for particular powers when they allow a fluid to pass through them. The juice which

flows from the Hoya carnosa, comes from the proper vessels, sap vessels, the same as the milky juice in the Asclepiads. These vessels, generally, however, have no partitions. If, then, the nutritive sap made a rapid transition from the spiral vessels into the cells (withered twigs, for instance, placed in water, very quickly erect their leaves), would it be seen? But this is not the place for the investigation of this subject; it was only necessary to give Dr. Schleiden's statement in his own words." (*Ray Reports.*)

I cannot say that Professor Link meets the question in a satisfactory manner: or at all shows, by what is very like special pleading, that spiral vessels are not air vessels. It has always appeared to me probable that one of the offices of the spiral thread coiled in the interior of the tubes of trachenchym, is to exclude fluids which would otherwise pass through the thin sides, which object it can effect by the mechanical obstacle opposed to fluids by the great additional thickness the spiral thread gives to the sides.

It requires no argument to prove that the office of CINENCHYMA is to convey the elaborated sap of a plant to the places where it is needed, and especially down the inner parts of the bark of exogens.

In regard to the functions of *air-cells* and *lacunæ*, it may be sufficient to remark, that in all cases in which they form a part of the vital system, as in water plants, they are cavities regularly built up of cellular tissue, and uniform in figure in the same species; in which case they serve to render parts buoyant, or are in some other manner manifestly connected with the peculiar mode of life of the plant in which they occur; while, on the other hand, where they are not essential to vitality, as in the pith of the Walnut, the Rice-paper plant, the stems of Umbellifers, and the like, they are ragged, irregular distentions of the tissue. In the former case they are intended to enable plants to float in water; in the latter, they are caused by the growth of one part more rapidly than another.

All these organs are held together by a *skin* or *epidermis*,

which incloses them under all circumstances except those mentioned at p. 132, &c. The function of this membrane is fourfold. It acts as a guard against injury, especially when, as in succulent plants, it acquires much thickness, in which cases, it may be regarded as a true vegetable hide. It is a perspiring organ, carrying off the superfluous water introduced into the system; being enabled to do this by the stimulating effect of light, independently of the action of dry air, or of its own vital force. It is a respiratory organ, allowing gaseous matters to pass freely through it in either direction. And finally, it is an organ of absorption, readily taking up water, whether as fluid or vapour, whenever it is presented to it. Dr. D. P. Gardner has made some experiments to prove its porosity, which will be found in a note.*

* The object in this place is to show, that the epidermis is not merely capable of transmitting particular gases, but that it obeys all the laws of a porous system. If this be found true for the bounding membrane, it will necessarily be true for the internal cellular structure.——Experiments were planned for the purpose of determining whether carbonic acid would penetrate into a vessel containing common air through a barrier of vegetable epidermis; and secondly, whether an inclosed mixture of gases of a theoretical composition would solicit the passage of both carbonic acid and oxygen, and at the same time evolve nitrogen.——A tube, five inches long and a third of an inch in bore, with a flattened and ground end, was closed by a piece of epidermis obtained from the leaf of the Madeira vine (Basella lucida). The tube was then immersed in a mercurial trough, and filled to within an inch of the membrane; on suspending it by a wire it did not leak, though there was a pressure of three inches of mercury. Clear lime-water was admitted to displace the mercury, and the arrangement covered by a small bell-jar containing atmospheric air with 10 per cent. carbonic acid. In five hours the lime water exhibited a distinct pellicle of carbonate of lime. The same result was obtained in more or less time with the epidermis of the cabbage, Alanthus alata, Chenopodium album, and several species of Sedum. Some specimens, as that from the balsam, leaked so fast as not to sustain any mercurial column, whilst others maintained four inches for thirty hours and more.——A similar tube was closed with epidermis, and contained an atmosphere of nitrogen 87, oxygen 13 per cent. over mercury, and was covered with a bell-jar as above. The included volume increased during nine hours from 400 to 433 measures, and on analysis consisted of N 76, O 17, CO_2 7 per cent. Hence the membrane comported itself as a simple porous tissue, allowing nitrogen to pass out and admitting oxygen and carbonic acid. This experiment was also repeated with the foregoing specimens of epidermis, and no absolute variation perceived. (*Philosophical Magazine*, xxviii. 425.)

CHAPTER V.

OF THE ROOT.

It is the business of the root to absorb nutriment from the soil, and to transmit it upwards into the stem and leaves; and also to fix the plant firmly in the earth. Although moisture and gaseous matters are, no doubt, absorbed by the epidermis covering the leaves and bark of all plants, yet it is certain that the greater part of their food is taken up by the roots; which, hence, are not incorrectly considered vegetable mouths.

But it is not by the whole surface of the root that the absorption of nutriment takes place; it is the spongioles almost exclusively, and the adjacent surface, to which that office is confided: and hence their immense importance in vegetable economy, the necessity of preserving them in transplantation, and the death that often follows their destruction. This was shown in the following manner, by Senebier:—He took a radish, and placed it in such a position that the extremity only of the root was plunged in water: it remained fresh several days. He then bent back the root, so that its extremity was curved up to the leaves: he plunged the bent part in water, and the plant withered soon; but it recovered its former freshness upon relaxing the curvature, and again plunging the extremity of the root into the water.

This explains why forest trees, with very dense umbrageous heads, do not perish from drought in hot summers or in dry situations, where the earth often becomes mere dust for a considerable distance from their trunk, in consequence of their foliage turning off the rain; the fact is obviously that the roots near the stem are inactive, and have little or nothing to do as preservatives of life except by acting as conduits,

while the functions of absorption go on through the spongioles, which, being at the extremities of the roots, are placed beyond the influence of the branches, and extend wherever moisture is to be found. This property prevents a plant from exhausting the earth in which it grows; for, as the roots are always spreading further and further from the main stem, they are continually entering new soil, the nutritious properties of which are unexhausted.

It is generally believed that roots increase *only* by their extremities, and that, once formed, they never undergo any subsequent elongation. This was first noticed by Du Hamel, who passed fine silver threads through young roots at different distances, marking on a glass vessel corresponding points with some varnish: all the threads, except those that were within two or three lines of the extremity, always continued to answer to the dots of varnish on the glass vessel, although the root itself increased considerably in length. Variations in this experiment, which has also been repeated in another way by Knight, produced the same result, and the whole phenomenon appears to be one of those beautiful evidences of design which are so common in the vegetable kingdom. If plants growing in a medium of unequal resistance lengthened by an extension of their whole surface, the nature of the medium in which they grow would be in most cases such as the mere force of their elongation would be unable to overcome; and the consequence would be, that they would have a twisted, knotted, form, that would be unfavourable to the rapid transmission of fluid, which is their peculiar office. Lengthening, however, only at the extremities, and this by the continual formation of new matter at their advancing point, they insinuate themselves with the greatest facility between the crevices of the soil; once insinuated, the force of horizontal expansion speedily enlarges the cavity; and if they encounter any obstacle which is absolutely insurmountable, they simply stop, cease growing in that particular direction, and follow the surface of the opposing matter, till they again find themselves in a soft medium.

It is curious, however, to remark that, although this property of lengthening only by the ends of their roots seems

constant in most plants, yet that it is not impossible that it may be confined to roots growing in a resisting medium. From the following experiments it will be seen that in Orchids the root elongates independently of its extremity:—On the 5th of August I tied threads tightly round the root of a Vanilla, so that it was divided into three spaces, of which one was seven inches long; another four inches; and the third, which was the free-growing extremity, $1\frac{3}{8}$ inch. On the 19th of September the first space measured $7\frac{1}{8}$ inches; the second, $4\frac{3}{8}$ inches; and the third, or growing extremity, $2\frac{1}{8}$ inches. A root of Aerides cornutum was, on the 5th of August, divided by ligatures into spaces, of which the first measured 1 foot 3 inches; the second, $2\frac{1}{4}$ inches; the third, $3\frac{1}{8}$ inches; and the fourth, or growing end, $1\frac{1}{8}$ inch. On the 19th of September, the first space measured 1 foot $3\frac{1}{2}$ inches; the second, $2\frac{3}{4}$ inches; the third, $3\frac{1}{4}$ inches; and the fourth, $4\frac{3}{4}$ inches.

Occasionally roots appear destined to act as reservoirs of nutriment on which those of the succeeding year may feed when first developed, as is the case in the Orchis, the Dahlia, and others. But it must be remarked, that the popular notion extends this circumstance far beyond its real limits, by including among roots bulbs, tubers, and other forms of stem in a succulent state.

By some botanists, and among them by De Candolle, it has been thought that roots are developed from special organs, which are to them what leaf-buds are to branches; and this function has been assigned to those little glandular swellings so common on the willow, called *lenticular glands* by Guettard, and *lenticelles* by De Candolle. Such swellings appear, however, to be in fact the commencement of roots, produced by the first attempt of the woody matter of the longitudinal system to become free and to quit the stem.

Roots not only absorb fluid from the soil, but they have been said to return a portion of their peculiar secretions back again into it. Brugmans ascertained that the Pansy exuded an acid fluid from its spongioles; others found that various Euphorbiaceous and Cichoraceous plants form little knobs at

the extremity of their roots. In modern times more exact inquiries into this subject have been made by Macaire, who, in a paper in the *Transactions of the Physical Society of Geneva*, has given an account of his experiments:—He states that Chondrilla muralis, and Cichoraceous plants in general, secrete a matter analogous to opium; Leguminous plants, a substance similar to gum, with a little carbonate of lime; Grasses, a minute quantity of matter consisting of alkaline and earthy muriates and carbonates, with very little gum; Papaveraceous plants, a matter analogous to opium; and Euphorbias, a whitish yellow gum, and resinous matter of an acrid taste.

He also found that plants possess the power of freeing themselves from matter that is deleterious to them, by means of their roots. Acetate of lead is a well-known active vegetable poison; he took two bottles, one of which, A, was filled with pure water, and the other, B, with water holding acetate of lead in solution. He placed a plant of Mercurialis annua with half its roots plunged in A, and the other half in B. After a short time the water in the bottle A contained a notable proportion of acetate of lead, which must have been carried into the system by the roots in bottle B, and thrown off again by those in bottle A. He also states that various plants which had lain several days in water charged with lime, or acetate of lead, or nitrate of silver, or common salt, in small quantity, having been carefully washed and placed in pure water, gave back from their roots the deleterious matter they had absorbed.

At one time these supposed facts were expected to throw light upon what is called the rotation of crops: and some writers have gone so far as to reason in detail upon them. But other experiments, like those of Macaire, only performed with greater precautions, have not led to the same result; and root secretions are now regarded as unimportant, if not altogether apocryphal, except in cases where the roots are wounded.

M. Payen has ascertained (*Ann. des Sc.*, n. s., iii. 18.) that the roots of plants contain a large proportion of azotised

matter, which is so abundant in the spongioles, as immediately to give off ammoniacal vapours when decomposed by aid of heat. Aerial roots, especially those of many species of Pothos, contain more than such as are subterranean. This azotised matter is almost or entirely insoluble in water, and adheres inseparably to the cellular tissue: it is most abundant at the points of the spongioles, and gradually disappears in the interior of the root. It appears essential to the life of plants, and its large proportion at the extremities of the roots may help to explain why azotised manures are so peculiarly efficient. It also shows how the well known destructive effects of tannin upon roots take place, by precipitating the azotised matter, which is essential to the existence of roots.

Some experiments have been tried by Dr. D. P. Gardner in order to determine the action of roots upon the gases contained in the water which bathes them.

In June 1844 he commenced his observations upon the uninjured roots of Datura and blue grass. The plants were placed in vessels resembling a bird-fountain, filled with pump water, and capable of being replenished to compensate for the evaporation of the leaves, and also of collecting any gas passing from the roots. "Three sets of experiments were made: A, the roots and leaves were placed in darkness; B, both portions were exposed to bright diffused light; C, the leaves were illuminated, but the roots in darkness. On the evening of the 25th of June, two sets of plants were arranged according to these plans. The Daturas B, yielded the next morning at 11, a gas the composition of which was N 96·6, O 3·4 per cent.; these two plants were then placed in a dark cupboard for thirty-six hours and evolved no gas whatever; on again exposing them to light, they produced a mixture of N 96·2, O 3·8 per cent. as the mean of six analyses. The grass plants, B, gave off but little gas, and only enough was collected for two measures, which yielded a mean of N 96, O 4 per cent. The plants C conducted themselves in the same way as B; the Daturas gave gas for six analyses, the mean of which was N 96·5, O 3·5 per cent. The plants A, placed in darkness, gave no gas whatever,

although they were attended to for five days. We concluded that roots appear to evolve gas unequally in quantity; that the action of light on the leaves is essential to this phenomenon; and thirdly, the exposure of the root, does not seem to have any effect on the result. I do not believe that the gas is evolved from the interior of the plant, but that the roots disturb the equilibrium of the mixture in the water, so that all the carbonic acid is withdrawn, and most of the oxygen, leaving behind the sparingly soluble nitrogen, which acquires the elastic condition." That this gaseous disturbance was not a mechanical effect of light and heat, he satisfied himself by observations at the time; "and the results of Professor Morren (*Ann. de Chimie, &c.*, Sept. 1844) show that the sun's light liberates carbonic acid and nitrogen, accumulating oxygen in the water, which is opposed to the effects here observed."

"The gas of the pump-water was N 48, O 22, CO_2 30 per cent., therefore the roots absorbed carbonic acid and oxygen in the same way as a porous system containing the normal plant atmosphere, N 86·75, O 13·25 per cent.; this continued during daylight, or during the activity of the vegetable, but in darkness all the gas of the water is taken up without any selection." (*Phil. Mag.* xxviii. 427.)

There seems, however, to be no doubt that the roots of plants do give off carbonic acid. The discovery of this is claimed by Dr. John Murray, who, in a letter addressed to the Editor of the *Gardeners' Chronicle*, asserts that in 1818 he proved the fact experimentally by growing the bulbs of Hyacinths, &c. in distilled water. He adds, "I am possessed of a very remarkable specimen proving that the carbonic acid gas secreted by the roots of the Lichen does decompose the silicated alkali of glass. It is a piece of old glass from a window at St. Cross, near Winchester. When put into my hands, it was beautifully mantled with a brilliant Lichen; which being removed, discovered the surface of the glass beneath, corroded and completely grooved or wormed." This has been also ascertained by Messrs. Wiegmann and Polsdorff. It appears from their researches, as reported in the *Annals of Chemistry*, that the roots of living plants

disengage carbonic acid, and that this acid is capable of decomposing the silicates of the soil, which even resist the action of nitro-muriatic acid. This most curious discovery throws a new light upon the importance of carbonic acid to vegetation, and explains clearly what has been by no means evident, namely, the manner in which flinty substances prove beneficial to vegetation, and how minerals so hard as felspar are made to contribute to the maintenance of plants. Plants of Tobacco, Oats, Barley, Clover, &c., were grown in quartz-sand, which had been heated red-hot, and then digested for sixteen hours in dilute nitro-muriatic acid. One would have thought that after such treatment the quartz could have contained nothing capable of sustaining vegetable life; nevertheless, the plants grew in it, and their ashes were found to contain potassa, lime, magnesia, and siliceous earth, which had been obtained from the decomposition of the quartz-sand by the carbonic acid of the roots. Dr. Jackson of Boston U. S., has also observed that glasses in which Hyacinth bulbs had been grown, were corroded. He had also noticed the same effects on bottle glass, which had lain in garden mould, and supposes that plants have the power of decomposing glass as well as the felspar of granite, and of appropriating to their use the potash contained in it, and that this is the source of the potash contained in the ashes of plants. (*Proceedings of Boston Society.*)

CHAPTER VI.

OF THE STEM AND THE ORIGIN OF WOOD.

The general purpose of the stem is, to bear the leaves and other appendages of the axis aloft in the air, so that they may be freely exposed to light and atmospheric action; to convey fluids from the root upwards, and from above downwards; and, if woody, to store up a certain portion of the secretions of the species either in the bark or in the heartwood.

Various notions have from time to time been entertained about the PITH. The functions of brain, lungs, stomach, nerves, spinal marrow, have by turns been ascribed to it. Some have thought it the seat of fecundity, and have believed that fruit trees deprived of pith became sterile; others supposed that it was the origin of all growth; and another class of writers have declared that it is the channel of the ascent of sap.

It is probable that its real and only use is, to serve, in the infancy of a plant, for the reception of the sap upon which the young and tender vessels that surround it are to feed when they are first formed; a time when they have no other means of support. In the winter it is often rich in starch, which changes into gum in the progress of vegetation, and, in a state of solution, passes from the pith into the young organs in communication with the pith. It sometimes contains resinous and other insoluble matters, which has led Professor Morren to regard it as a "species of cloaca where substances henceforward useless accumulate."

Dutrochet considers it to act not only as a reservoir of nutriment for the young leaves, but also to be the place in which the globules which he calls nervous corpuscles are formed out of the elaborated sap (*L'Agent Immédiat*, &c.

p. 44. &c.); and Braschet imagines it and its processes to constitute the nervous system of plants!

The MEDULLARY SHEATH seems to perform an important part in the economy of plants; it diverges from the pith whenever a leaf is produced; and, passing through the petiole, ramifies among the cellular tissue of the blade, where it appears as veins: hence veins are always composed of bundles of woody tissue and spiral vessels. Thus situated, the veins are in the most favourable position that can be imagined for absorbing the fluid which, in the first instance, is conducted to the young pith, and which is subsequently impelled upwards through the woody tissue. So essential is the medullary sheath to vegetation in the early age of a branch, that, although the pith and the bark, and even the young wood, may be destroyed, without the life of a young shoot being much affected; yet, if the medullary sheath be cut through, the pith, bark, or wood, being left, the part above the wound will perish. It may be supposed, considering the large proportion of oxygen it contains, that its office is in part to convey that gas to places inaccessible to the external air, where it may combine with the carbon of such parts, and cause the production of carbonic acid; without a power of composing and decomposing which, no part exposed to light can long exist; or it may be the natural means of conveying into the atmosphere the oxygen produced by the decomposition of carbonic acid or of water in the innermost recesses of the stem.

The BARK acts as a protection to the young and tender wood, guarding it from cold and external accidents. It is also the medium in which the proper juices of the plant, in their descent from the leaves, are finally elaborated, and brought to the state which is peculiar to the species. It is from the bark that they are horizontally communicated to the medullary rays, which deposit them in the tissue of the wood. Hence, the character of timber is almost wholly dependent upon the influence of the bark, as is apparent from a vertical section of a grafted tree, through the line of

union of the stock and scion. This line will be sometimes found so exactly drawn, that the limits of the two are well defined even in old specimens: the woody tissue will be found uninterruptedly continuous through the one into the other, and the bark of the two indissolubly united; but the medullary rays emanating from the bark of each will be seen to remain as different as it was at the time when the stock and scion were distinct individuals. It is to be remarked, however, that bark has only a limited power of impelling secreted matter into the medullary rays; and that there are certain substances which, although abundant in bark, are scarcely found elsewhere; as, for instance, gum in a Cherry tree. This substance exists in the wood in so slight a degree as probably not to exceed in quantity what is to be found in most plants, whether they are obviously gummiferous or not. Are we from this to infer that the medullary rays have a power of rejecting certain substances? or, that their tissue is impermeable to fluids of a particular degree of density? or, that they only take up what settles down the bark through its cellular system, and that gum, descending by the woody system, is not in that kind of contact with the medullary rays which is requisite in order to enable the latter to take it up?

As the bark, when young, is green like the leaves, and as the latter are manifestly a mere dilatation of the former, it is highly probable, as Knight believes, that the bark exercises an influence upon the fluids deposited in it wholly analogous to that exercised by the leaves, which will be hereafter explained. Hence it has been named, with much truth, the universal leaf of a vegetable. In fact, in many succulent plants, there is no other part capable of performing the function of leaves.

The business of the MEDULLARY RAYS is, to maintain a communication between the bark, in which the secretions receive their final elaboration, and the centre of the trunk, in which they are at last deposited. This is apparent from tangental sections of dicotyledonous wood manifesting an evident exudation of liquid matter from the

wounded medullary rays, although no such exudation is elsewhere visible. In endogens, in which there appears less necessity for maintaining a communication between the centre and circumference, there are no special medullary rays. These rays also serve to bind firmly together the whole of the internal and external parts of a stem, and they give the peculiar character by which the wood of neighbouring species may be distinguished. If plants had no medullary rays, their wood would probably be, in nearly allied species, undistinguishable; for we are scarcely aware of any appreciable difference in the appearance of woody or vascular tissue; but the medullary rays (the *silver grain* of carpenters), differing in abundance, in size, and in other respects, impress characters upon the wood which are extremely well marked. Thus, in the cultivated Cherry, the plates of the medullary rays are thin, the adhesions of them to the bark are slight, and hence a section of the wood of that plant has a pale, smooth, homogeneous appearance; but in the wild Cherry the medullary plates are much thicker, they adhere to the bark by deep broad spaces, and are arranged with great irregularity, so that a section of the wood of that variety has a deeper colour, and a twisted, knotty, very uneven appearance. In Quercus sessiliflora the medullary rays are thin, and so distant from each other that the plates of wood between them do not readily break laterally into each other, if a wedge is driven into the end of the trunk in the direction of its cleavage: on the contrary, the medullary rays of Quercus pedunculata are hard, and so close together that the wood may be rent longitudinally without difficulty; hence the wood of the latter is the only kind that is fit for application to park paling.

As the medullary rays develope in a horizontal direction only, when two trees in which they are different are grafted or budded together, the wood of the stock will continue to preserve its own peculiarity of *grain*, notwithstanding its being formed by the woody matter sent down by the scion; for it is the horizontal development that gives its character to the "grain of wood," and not the perpendicular pleurenchyma encased in it.

The WOOD is at once the support of all the deciduous organs of respiration, digestion, and fertilisation; the reservoir of the secretions peculiar to individual species; and also the magazine from which newly forming parts derive their sustenance, until they can establish a communication with the soil.

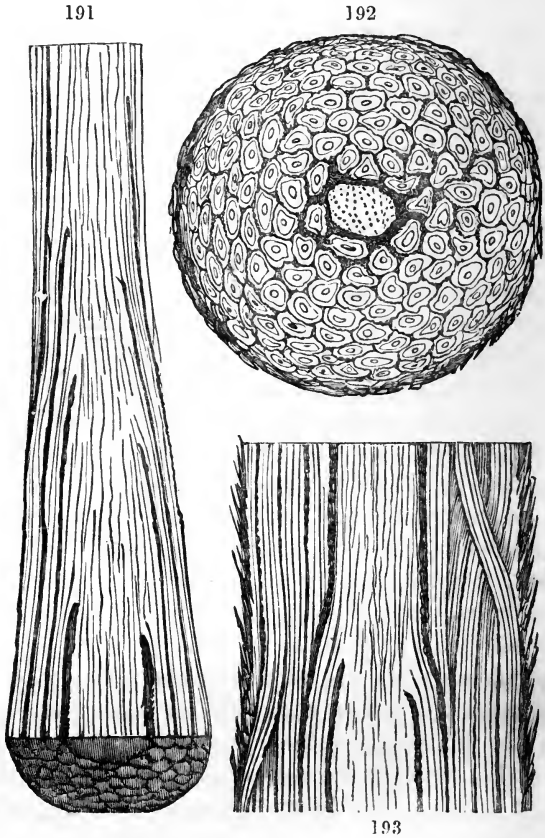
Regarding the precise manner in which it is created, there has been great diversity of opinion. Linnæus thought it was produced by the pith; Grew, that the liber and wood were deposited at the same time in a single mass which afterwards divided in two, the one half adhering to the centre, the other to the circumference. Malpighi conceived that the wood of one year was produced by an alteration of the liber of the previous season. Duhamel believed that it was deposited by the secretion existing in Exogens between the bark and wood, and called cambium: he was of opinion that this cambium was formed in the bark, and became converted into both cellular and woody tissue; and he demonstrated the fallacy of those theories according to which new wood is produced by the wood of a preceding year. He removed a portion of bark from a Plum tree; he replaced this with a similar portion of a Peach tree, having a bud upon it. In a short time a union took place between the two. After waiting a sufficient time to allow for the formation of new wood, he examined the point of junction, and found that a thin layer of wood had been formed by the Peach bud, but none by the wood of the Plum, to which it had been tightly applied. Hence he concluded that alburnum derives its origin from the bark, and not from the wood. Many similar experiments were instituted with the same object in view, and they were followed by similar results. Among others, a plate of silver was inserted between the bark and the wood of a tree, at the beginning of the growing season. It was said, that, if new wood were formed by old wood, it would be subsequently found pushed outwards, and continuing to occupy the same situation; but that, if new wood were deposited by the bark, the silver plate would in time be found buried beneath new layers of wood. In course of time the plate was examined, and was found inclosed in wood.

Hence the question as to the origin of the wood seemed settled; and there is no doubt that the experiments of Duhamel are perfectly accurate, and satisfactory as far as they go. It soon, however, appeared, that, although they certainly proved that new wood is not produced by old wood, it was not equally clear that it originated from the bark. Accordingly a new set of experiments was instituted by Knight, for the purpose of throwing a still clearer light upon the production of the wood. Having removed a ring of bark from both above and below a portion of bark furnished with a leaf, he remarked that no increase took place in the wood above the leaf, while a sensible augmentation was observable in the wood below the leaf. It was also found, that, if the upper part of a branch be deprived of leaves, the branch will die down to the point where leaves have been left, and below that will flourish. Hence the inference was drawn, that the wood is not formed out of the bark as a mere deposit from it; but that it is produced from matter elaborated in the leaves and sent downwards, either through the vessels of the inner bark, along with the matter for forming the liber, by which it is subsequently parted with; or that it and the liber are transmitted distinct from one another, the one adhering to the alburnum, the other to the bark. Knight was of opinion that two distinct sets of vessels are sent down, one belonging to the liber, the other to the alburnum; and if a branch of any young tree, the wood of which is formed quickly, be examined when it is first bursting into leaf, these two sets may be distinctly seen and traced. Take, for instance, a branch of Lilac in the beginning of April, and strip off its bark: the new wood will be distinctly seen to have passed downwards from the base of each leaf, diverging from its perpendicular course, so as to avoid the bundle of vessels passing into the leaf beneath it; and, if the junction of a new branch with that of the previous year be examined, it will be found that the wood already seen proceeding from the base of the leaves, having arrived at this point, has not stopped there, but has passed rapidly downwards, adding to the branch an even layer of young ligneous matter, and turning off at every projection which impedes it, just as the

water of a steady but rapid current would be diverted from its course by obstacles in its stream. Again, in Guaiacum wood, the descending tubes of pleurenchym cross and interlace each other, in a manner that is unintelligible upon the supposition of wood being formed by the mere deposit of secreted matter. If the new wood were a mere deposit of the bark, the latter, as it is applied to every part of the old wood, would deposit the new wood equally over the whole surface of the latter, and the deviation of the fibres from obstacles in their downward course would scarcely occur. This, therefore, in my mind, places the question as to the origin of the wood beyond all further doubt. Or, if further evidence were required, it would be furnished by a case adduced by Achille Richard, who states that he saw, in the possession of Du Petit Thouars, a branch of Robinia Pseudacacia on which R. hispida had been grafted. The stock had died; but the scion had continued to grow, and had emitted from its base a sort of plaster formed of very distinct fibres, which surrounded the extremity of the stock to some distance, forming a kind of sheath; and thus demonstrating incontestably that wood does descend from the base of the scion to overlay the stock. The singular mode of growth in Pandanus is equally instructive. In that plant, the stem, next the ground, is extremely slender; a little higher up it is thicker, and emits aerial roots, which seek the soil and act as stays upon the centre. As the stem increases in height, it also increases notably in diameter, continuing to throw out aerial roots. If the roots were pruned away, the stem would be an inverted cone; but, if we add to the actual thickness of the base of the stem the capacity of the aerial roots at that part, the two together will be about equal to the capacity of the stem at the apex; which suggests the idea that the woody matter that descends from the leaves may really be their roots, passing through the horizontal cellular system of the stem. An analogous but much more remarkable case is the following mentioned by me in the *Penny Cyclopædia*, article Endogens, vol. ix. p. 396. In an unpublished species of Barbacenia from Rio Janeiro, allied to B. purpurea, the stems appear externally like those of any other rough-barked plant, only

that their surface is unusually fibrous and ragged when old, and closely coated by the remains of sheathing leaves when young. Upon examining a transverse section of it, the stem is found to consist of a small, firm, pale, central circle having the ordinary endogenous organisation, and of a large number of smaller and very irregular oval spaces pressed closely together, but having no organic connection; between these are traces of a chaffy ragged kind of tissue which seems as if principally absorbed and destroyed. (See *fig.* 192.)

A vertical section of the thickest part of this stem exhibits,



in addition to a pale, central, endogenous column, woody branches crossing each other or lying parallel, after the

manner of the ordinary ligneous tissue of a Palm stem (*fig.* 193.), only the bundles do not adhere to each other, and are not embodied, as usual, in a cellular substance. These bundles may be readily traced to the central column, particularly in the younger branches (*fig.* 191.), and are plainly the roots of the stem, of exactly the same nature as those aerial roots which serve to stay the stem of a Screw Pine (Pandanus). When they reach the earth, the woody bundles become more apparently roots, divided at their points into fine segments, and entirely resembling on a small scale the roots of a Palm-tree. The central column is much smaller at the base of the stem, than near the upper extremity. This would seem to prove that the woody bundles of the endogenous stem are roots emitted by leaves, plunging down through their whole length into the cellular substance of the stem in ordinary cases; but, in Barbacenia, soon quitting the stem, and continuing their course downwards on the outside. The observation of Du Petit Thouars, that, when Dracænas push forth branches, each of the latter produces from its base a quantity of fibres, which are interposed between the cortical integument and the body of the wood, forming a sort of plaster analogous to what is found in the graft of an Exogen; and that, of the fibres just mentioned, the lowermost have a tendency to descend, while those originating on the upper side of the branch turn downwards, and finally descend also; had already rendered the above-mentioned conclusion probable.

Mirbel, who formerly advocated the doctrine of wood being deposited by bark, has admitted the opinion to be no longer tenable; and has suggested, in its room, that wood and bark are independent formations, created out of cambium: not meaning thereby merely the viscid secretion found in the spring between the bark and wood of Exogens; but that universal organic mucus, spoken of at p. 7 of the first volume of this work. In other words, out of what English physiologists call organisable matter.

Aware of the difficulties in the way of the old explanations of the formation of wood, Du Petit Thouars, an ingenious French physiologist, who had possessed opportunities of examining the growth of vegetation in tropical countries,

proposed a theory, which, although in many points similar to one previously invented by his countryman, De la Hire, is nevertheless, from the facts and illustrations brought by the French philosopher to his aid, to be considered legitimately as his own. The attention of Du Petit Thouars appears to have been first especially called to the real origin of wood by having remarked, in the Isle of France, that the branches emitted by truncheons of Dracæna (with which hedges are formed in that colony) root between the rind and old wood, forming rays, of which the axis of the new shoot is the centre. These rays surround the old stem; the lower ones at once elongated greatly towards the earth, and the upper ones gradually acquire the same direction; so that at last, as they become disentangled from each other, the whole of them pass downwards to the soil. Reflecting upon this curious fact, and upon others which I have not space to detail, he arrived at this conclusion; that it is not merely in the property of increasing the species that buds agree with seeds, but that they emit roots in like manner; and that the wood and liber are both formed by the downward descent of bud-roots, at first nourished by the moisture of the cambium, and finally embedded in the cellular tissue which is the result of the organisation of that secretion. That first tendency of the embryo, when it has disengaged itself from the seed, to send roots downwards and a stem and leaves upwards, and to form buds in the axils of the latter, is in like manner possessed by the buds themselves; so that plants increase in size by an endless repetition of the same phenomenon.

Hence a plant is formed of multitudes of buds or fixed embryos, each of which has an independent life and action; by its elongation upwards forming new branches and continuing itself, and by its elongation downwards forming wood and bark; which are therefore, in Du Petit Thouars's opinion, a mass of roots.

This opinion would probably have been more generally received, if it had not been too much mixed up with hypothetical statements, to the reception of which there are strong objections; as, for example, that mentioned in the last paragraph.

It has, however, had the advantage of being supported by M. Gaudichaud; an account of whose hypothesis is given in the sixth edition of Achille Richard's *Nouveaux Elémens de Botanique*, p. 167. The principal peculiarity in M. Gaudichaud's views consists in his assigning the growth of plants to a sort of polarity produced by the action of two opposite systems, of which the one, or *ascending*, consists of trachenchym exclusively, the other, or *descending*, of bothrenchym and pleurenchym. The line of demarcation between them is called the *mesocauleorhiza*. The leaf would appear to be regarded as a form of stem divided into three parts, of which the lowest is the internode from which the leaf emanates, the middle the petiole, the upper the lamina. The line of demarcation between the internode and petiole is called the *mesophytum*; that between the lamina and petiole the *mesophyllum*.

Setting aside mere hypothesis it seems incontestable that wood, in whatever manner it is deposited, is created out of organisable matter prepared in the leaves, or their equivalents, and therefore derived from them. This being so it matters nothing whether the matter descending from leaves, and acquiring the condition of wood, be theoretically called roots, or by some other name: it is certainly descending matter.

The most important of the objections which have been taken to this opinion are the following:—If wood were really organised matter emanating from the leaves, it must necessarily happen that in grafted plants the stock would in time acquire the nature of the scion, because its wood would be formed entirely by the addition of new matter, said to be furnished by the leaves of the scion. So far is this, however, from being the fact, that it is well known that, in the oldest grafted trees, there is no action whatever exercised by the scion upon the stock; but that, on the contrary, a distinct line of organic demarcation separates the wood of one from the other, and the shoots emitted from the stock, by wood said to have been generated by the leaves of the scion, are in all respects of the nature of the stock. Again, if a ring of bark from a red-wooded tree is made to grow in the room of a similar ring of bark of a white-wooded tree, as it easily

may be made, the trunk will increase in diameter, but all the wood beneath the ring of red bark will be red, although it must have originated in the leaves of the tree which produces white wood. It is further urged, that, in grafted plants, the scion often overgrows the stock, increasing much the more rapidly in diameter; or that the reverse takes place, as when Pavia lutea is grafted upon the common horsechestnut; and that these circumstances are inconsistent with the supposition that wood is organic matter engendered by leaves. To these statements there is nothing to object as mere facts, for they are true; but they certainly do not warrant the conclusions which have been drawn from them. One most important point is overlooked by those who employ such arguments, namely, that in all plants there are two distinct simultaneous systems of growth, the cellular and the fibro-vascular, of which the former is horizontal, and the latter vertical. The cellular gives origin to the pith, the medullary rays, and the principal part of the cortical integument; the fibro-vascular, to the wood and a portion of the bark: so that the axis of a plant may be not inaptly compared to a piece of linen, the cellular system being the woof, the fibro-vascular the warp. It has also been shown by Knight and De Candolle that buds are exclusively generated by the cellular system, while roots are evolved from the fibro-vascular system. Now, if these facts are rightly considered, they will be found to offer an obvious explanation of the phenomena appealed to by those botanists who think that wood cannot be matter generated in an organic state by the leaves. The character of wood is chiefly owing to the colour, quantity, size, and distortions of the medullary rays, which belong to the horizontal system: it is for this reason that there is so distinct a line drawn between the wood of the graft and stock; for the horizontal systems of each are constantly pressing together with nearly equal force, and uniting as the trunk increases in diameter. As buds from which new branches elongate are generated by cellular tissue, they also belong to the horizontal system: and hence it is that the stock will always produce branches like itself, notwithstanding the long superposition of new wood which has been taking place in it from the scion.

The case of a ring of red bark always forming red wood beneath it, is precisely of the same nature. After the new bark has adhered to the mouths of the medullary rays of the stock, and so identified itself with the horizontal system, it is gradually pushed outwards by the descent of woody matter from above through it; but, in giving way, it is constantly generating red matter from its horizontal system, through which the wood descends, and thus acquires a colour not properly belonging to it. With regard to the instances of grafts overgrowing their stocks, or *vice versâ*, it seems that these are susceptible of explanation on the same principle. If the horizontal system of both stock and scion has an equal power of lateral extension, the diameter of each will remain the same; but, if one grows more rapidly than the other, the diameters will necessarily be different: where the scion has a horizontal system that developes more rapidly than that of the stock, the latter will be the smaller, and *vice versâ*. It is, however, to be observed, that in these cases plants are in a morbid state, and will not live for any considerable time.

Another case was, that if a large ring of bark be taken from the trunk of a vigorous elm or other tree, without being replaced with anything, new beds of wood will be found in the lower as well as upper part of the trunk; while no ligneous production will appear on the ring of wood left exposed by the removal of the bark. Now this is so directly at variance with the observations of others, that it is impossible to receive it as an objection until its truth shall have been demonstrated. It is well known, that, if the least continuous portion of liber be left upon the surface of a wound of this kind, that portion is alone sufficient to establish the communication between the upper and lower lips of the wound; but, without some such slight channel of union, it is contrary to experience that the part of a trunk below an annular incision should increase by the addition of new layers of wood until the lips of the wound are united, unless buds exist upon the trunk below the ring. The horizontal parenchymatous system may, however, go on growing, and so form new layers.

Dutrochet mentions some cases of extraordinary longevity in the stock of Pinus Picea, after the trunk had been felled, and which he supposes fatal to the theory of wood being formed by the descent of organised matter. He says that, in the year 1836, a stock of Pinus Picea, felled in 1821, was still alive, and had formed 14 thin new layers of wood, that is, one layer each year; and another, felled in 1743, was still in full vegetation, having formed 92 thin layers of wood, or one each year. But, it is now ascertained that these roots are connected with living stems in consequence of having become grafted under ground to the roots of the latter.

The observations of Mirbel on the origin of the woody bundles of Palm trees, from which it appears that the bundles first appear isolated in the cellular matter of the buds, and then direct themselves upwards into the leaves and downwards into the trunk, are certainly opposed to the possibility of regarding wood as the roots of leaves. And the difficulty of admitting the theory is much increased by the existence in bark of the embryo buds, already described, vol. 1. p. 177; and by M. Decaisne's statement, that in the Beet-root, when new vascular tissue is produced, it, in the beginning, is distinct from the previously formed vascular tissue.

The singular examples of carved figures being found in the interior of trees also militate somewhat against the theory of wood being a form of roots, and are better explicable upon the supposition of a gradual superficial deposit. A very curious example of this is to be found in the *Gardeners' Chronicle* for 1841, p. 828; others have been occasionally met with; and Link has figured one in his *Icones Selectæ,* part 2. t. 2. fig. 7, which he speaks of thus:—I found such letters in a Lime tree near Berlin, on an estate belonging to the deceased minister, Count von Lottum; the letters on the one side of the split piece were hollow, on the other elevated, and the cavity had evidently been filled up again with a woody substance. This filling-up substance, on making a transverse incision, exhibited rather irregular layers, with a moderate magnifying power. And on being magnified by 315 diameters, it evidently consisted of strata of larger and smaller cells, partly filled up, partly empty, with interstices. The

circumstance, however, which appears particularly remarkable, is, that the internal structure of the filling-up substance, on a longitudinal incision, corresponded very nearly with the old wood situated next to it, with the difference only, that spiroids existed in the latter, which were entirely absent in the new wood. It will be seen, therefore, that the formation of layers is peculiar to the wood, and is by no means caused by any external influences.

CHAPTER VII.

OF THE LEAVES.

LEAVES are at once organs of respiration, digestion, and nutrition. They elaborate the crude sap impelled into them from the stem, decomposing its water, adding to it carbon, and exposing the whole to the action of air; and while they supply the necessary food to the young tissue that passes downwards from them and from the buds, in the form of alburnum and liber, they also furnish nutriment to all the parts immediately above and beneath them.

There are many experiments to show that such is the purpose of the leaves. If a number of rings of bark are separated by spaces without bark, those which have leaves upon them will live much longer than those which are destitute of leaves. If leaves are stripped from a plant before the fruit has commenced ripening, the fruit will fall off and not ripen. If a branch is deprived of leaves for a whole summer, it will either die or not increase in size perceptibly. The presence of cotyledons, or seminal leaves, at a time when no other leaves have been formed for nourishing the young plant, is considered a further proof of the nutritive purposes of leaves: if the cotyledons are cut off, the seed will either not vegetate at all, or slowly and with great difficulty; and if they are injured by old age, or any other circumstance, this produces a languor of habit which only ceases with the life of the plant, if it be an annual. This is the reason why gardeners prefer old melon and cucumber seeds to new ones: in the former the nutritive power of the seed-leaves is impaired, the young plant grows slowly, a languid circulation is induced from the beginning; by which excessive luxuriance is checked, and fruit formed rather than leaves or branches.

Nothing can be more admirable than the adaptation of

leaves to such purposes as those just mentioned. It has been already shown, in speaking of the anatomy of a leaf, that in most cases it consists of a thin plate of cellular tissue pierced by air vessels and woody tissue, and enclosed within a hollow empty stratum of cells forming epidermis. Beneath the upper epidermis the cells of the parenchym are compactly arranged perpendicular to the plane of the epidermis, and have but a small quantity of air cavities among them. Beneath the lower epidermis the parenchym is loosely arranged parallel with it, and is full of air chambers communicating with the stomates. The epidermis prevents too rapid an evaporation beneath the solar rays, and thickens when it is especially necessary to control evaporation more powerfully than usual; thus in the Oleander, which has to exist beneath the fervid sun of Barbary, in a parched country, the epidermis is composed of not less than three layers of thick-sided cells. To furnish leaves with the means of parting with superfluous moisture, at periods when the epidermis offers too much resistance, there are stomates which act like valves, and open to permit its passage: or when, in dry weather, the stem does not supply fluid in sufficient quantity from the soil for the nourishment of the leaves, these same stomates open themselves at night, and allow the entrance of atmospheric moisture, closing when the cavities of the leaf are full. In submersed leaves, in which no variation can take place in the condition of the medium in which they float, both epidermis and stomates would be useless, and accordingly neither exists. For the purpose of exposing the fluids contained in leaves to the influence of air, the epidermis would frequently offer an insufficient degree of surface. In order, therefore, to increase the quantity of surface exposed, the tissue of the leaf is cavernous, each stomate opening into a cavity beneath it, which is connected with multitudes of intercellular passages. But, as too much fluid might be lost by evaporation in parts exposed to the sun, we find that the cells of the upper stratum of parenchym only expose their ends to the epidermis, and interpose a barrier between the direct rays of the sun and the more lax respiring portion forming the under stratum. It is not improbable, moreover, that those cells which form

the upper stratum perform a function analogous to that of the stomach in animals, digesting the crude matter they receive from the stem; and that the lower stratum takes up the matter so altered, and submits it to the action of the atmosphere, which must enter the leaf purely by means of the stomates. Nor are the stomates and the cavernous parenchym of the leaf the only means provided for the regulation of its functions. Hairs, no doubt, perform no mean office in their economy. In some cases these processes seem destined only for protection against cold, as in those plants in which they only clothe the buds and youngest leaves, falling away as soon as the tender parts have become hardened; but it cannot be doubted that in many others they are absorbent organs, intended to collect humidity from the atmosphere. In succulent plants, or in such as grow naturally in shady places, where moisture already exists in abundance, they are usually wanting; but in hot, dry, exposed places, where it is necessary that the leaf should avail itself of every means of collecting its food, there they abound, lifting up their points and separating at the approach of the evening dews, but again falling down, and forming a layer of minute cavities above the epidermis, as soon as the heat of the sun begins to be perceived.

Whether or not leaves have the power of absorbing atmospheric fluid, independently of their hairs, has been doubted. By some it is believed that they do possess such a power, and that absorption takes place indifferently by either the upper or under surface of the leaf, but that some plants absorb more powerfully by one surface than by the other. Bonnet found that, while the leaves of Arum, the Kidneybean, the Lilac, the Cabbage, and others, retained their verdure equally long, whichever side was deprived of the power of absorption, the Plantago, some Verbascums, the Marvel of Peru, and others, lost their life soonest when the *upper* surface was prevented from absorbing; and that, in a number of trees and shrubs, the leaves were killed very quickly by preventing absorption by the *lower* surface. But others contend that Bonnet's experiments merely produced a hindrance of evaporation in some cases, and of respiration in others; and that leaves have,

in fact, no power of attracting fluid. In proof of this it is urged, that, if leaves are made to float on coloured infusions, no colouring matter enters them. Considering, however, the thinness of the epidermis of many plants, and the great permeability of vegetable membrane in general, it must be admitted that they do possess the power of absorption which Bonnet contends for. This is sufficiently proved by the effect obviously produced by a shower of rain in the summer, or by syringing the fading plants in a hothouse.

Leaves usually are so placed upon the stem that their upper surface is turned towards the heavens, their lower towards the earth; but this position varies occasionally. In some plants they are imbricated, so as to be almost parallel with the stem; in others they are deflexed till the lower surface becomes almost parallel with the stem, and the upper surface is far removed from opposition to the heavens. A few plants, moreover, invert the usual position of the leaves by twisting the petiole half round, so that either the two margins become opposed to earth and sky, or the lower surface becomes uppermost: the former is especially the case with plants bearing phyllodia, or spurious leaves.

At night a phenomenon occurs in plants which is called their sleep: it consists in the leaves folding up and drooping, as those of the Sensitive Plant when touched. This scarcely happens perceptibly except in compound leaves, in which the leaflets are articulated with the petiole, and the petiole with the stem: it is supposed to be caused by the absence of light.

After the leaves have performed their functions, they fall off: this happens at extremely unequal periods in different species. In some they all wither and fall off by the end of a single season; in others, as the Beech and Hornbeam, they wither in the autumn, but do not fall off till the succeeding spring; and, in a third class, they neither wither nor fall off the first season, but retain their verdure during the winter, and till long after the commencement of another year's growth: these last are our evergreens. Mirbel distinguishes

leaves into three kinds, as characterised by their periods of falling :—

1. *Fugacious,* or *caducous,* which fall shortly after their appearance; as in Cactus.

2. *Deciduous,* or *annual,* which fall off in the autumn; as the Apple.

3. *Persistent, evergreen,* or *perennial,* which remain perfect upon the plant beyond a single season; as Holly, common Laurel, &c.

With regard to the cause of the fall of the leaf a number of explanations have been given, which may be found in *Willdenow's Principles of Botany,* p. 336. The two most worth recording are those of Du Petit Thouars and De Candolle.

If you watch the progress of a tree, of the Elder, for example, says the former writer, you will perceive that the lowest leaves upon the branches fall long before those at the extremities. The cause of this may be, perhaps, explained upon the following principle :—In the first instance, the base of every leaf reposes upon the pith of the branch, to the sheath of which it is attached. But, as the branch increases in diameter by the acquisition of new wood, the space between the base of the leaf and the pith becomes sensibly augmented. It has, therefore, been necessary that the fibres by which the leaf is connected with the pith should lengthen, in order to admit the deposition of wood between the bark and the pith. Now how does this elongation take place? As the bundles of fibres which run from the pith into the leaf-stalk are at first composed only of spiral vessels, it is easy to conceive that they may be susceptible of elongation by unrolling. And in this seems to lie the mystery of the fall of the leaf; for the moment will come when the spiral vessels are entirely unrolled, and incapable of any further elongation: they will, therefore, by the force of vegetation, be stretched until they snap, when the necessary communication between the branch and the leaf is destroyed, and the latter falls off.

De Candolle explains the matter otherwise and better. The increase of leaves, he says, whether in length or in breadth, generally attains its term with considerable rapidity;

the leaf exercises its functions for a while, and enjoys the fullness of its existence; but, by degrees, in consequence of exhaling pure water, and preserving in the tissue the earthy matters which the sap had carried there, the vessels harden and their pores are obstructed. This time in general arrives the more rapidly as evaporation is more active: thus we find the leaves of herbaceous plants, or of trees which evaporate a great deal, fall before the end of the year in which they were born; while those of succulent plants, or of trees with a hard and leathery texture, which, for one cause or another, evaporate but little, often last several years. We may, therefore, in general say that the duration of life in leaves is in inverse proportion to the force of their evaporation. When this time has arrived, the leaf gradually dries up, and finishes by dying: but the death of the leaf ought not to be confounded with its fall; for these two phenomena, although frequently confounded, are in reality very different. All leaves die some time or other; but some are gradually destroyed by exterior accidents, without falling; while others fall, separating from the stem at their base, and drop at once, either already dead, or dying, or simply unhealthy.

The main cause is, however, to be sought in the different rates at which leaves and bark grow. So long as they continue to grow at the same rate they adhere to each other: but if, from whatever cause, the leaf grows more slowly than the bark, it drops; or if the tissue of a leaf contracts suddenly, while the bark remains distended, we obtain the same result. The latter seems to be one of the reasons why leaves are instantly cast in the autumn after a sudden frost; the former is the obvious explanation of the fall of evergreen leaves upon the renewal of growth in the spring.

CHAPTER VIII.

OF THE BRACTS AND FLORAL ENVELOPES.—DISENGAGEMENT OF CALORIC.

THE bracts, when but slightly different in colour and form from leaves, no doubt perform functions similar to those of the latter organs; and, when coloured and petaloid, it may be presumed that they perform the same office as the corolla. Nothing, therefore, need be said of them separately.

With regard to the calyx, corolla, and disc, I chiefly follow Dunal's statements in his ingenious pamphlet, *Sur les Fonctions des Organes floraux colorés et glanduleux:* 4to; Paris, 1829.

The calyx seems, when green, to perform the functions of leaves, and to serve as a protection to the petals and sexual organs; when coloured, its office is undoubtedly the same as that of the corolla.

The common notion of the use of the corolla is, that, independently of its ornamental appearance, it is a protection to the organs of fertilisation; but, if it is considered that the stamens and pistils have often acquired consistence enough to be able to dispense with protection *before the petals are enough developed* to defend them, it will become more probable that the protecting property of the petals, if any, is of secondary importance only.

Among the many speculations to which these beautiful ornaments have given birth is one, that the petals and disc are the agents of a secretion which is destined to the nutrition of the anthers and young ovules. These parts are formed in the flower-bud long before they are finally called into action; in the Almond, for example, they are visible some time before the spring, beneath whose influence they are destined to

expand. In that plant, just before the opening of the flower, the petals are folded up; the glandular disc that lines the tube of the calyx is dry and scentless; and its colour is at that time dull, like the petals at the same period. But, as soon as the atmospheric air comes in direct contact with these parts, the petals expand and turn out of the calyx, the disc enlarges, and the aspect of both organs is altered. Their compact tissue gradually acquires its full colour and velvety surface; and the surface of the disc, which before was dry, becomes lubricated by a thick liquid, exhaling that smell of honey which is so well known. At this time the stamens perform their office. No sooner is that effected than they wither, the petals shrivel and fall away, the secretion from the disc gradually dries up, and, in the end, the disc perishes along with the other organs to which it appertained. If the disc of an Almond flower be broken before expansion, it will be seen that the fractured surface has the same appearance as those parts which in certain plants contain a large quantity of fæcula, as the tubers of the Potato, Cyperus esculentus, &c. This led Dunal to suspect that the young discs also contained fæcula: which he afterwards ascertained, by experiment, to be the fact in the spadix of Arum italicum before the dehiscence of the anthers; but, subequently to their bursting, no trace of fæcula could be discovered. Hence he inferred that the action of the air upon the humid fæcula of the disc had the effect of converting it into a saccharine matter fit for the nutrition of the pollen and young ovules; just as the fæcula of the albumen is converted in germination into nutritive matter for the support of the embryo.

In support of this hypothesis, Dunal remarks that the conditions requisite for germination are analogous to those which cause the expansion of a flower. The latter opens only in a temperature above 32° Fahr., that of 10° to 30° centig. (50° to 86° Fahr.) being the most favourable; it requires a considerable supply of ascending sap, without the watery parts of which it cannot open; and, thirdly, flowers, even in aquatic plants, will not develope in media deprived of oxygen.

Thus the conditions required for germination and for

flowering are the same; the phenomena are in both cases also very similar.

When a germinating seed has acquired the necessary degree of heat and moisture, it abstracts from the air a portion of its oxygen, and gives out an equal quantity of carbonic acid gas; but as one volume of the latter gas equals one volume of oxygen, it is evident that the seed is, in this way, deprived of a part of its carbon. Some changes take place in the albumen and cotyledons; and, finally, the fæcula that they contained is replaced by saccharine matter. In like manner, a flower, while expanding, robs the air of oxygen, and gives out an equal volume of carbonic acid; and a sugary matter is also formed, apparently at the expense of the fæcula of the disc or petals.

The quantity of oxygen converted into carbonic acid in germination is, *cæteris paribus*, in proportion to the weight of the seed; but some seeds absorb more than others. Theodore de Saussure has shown that exactly the same phenomenon occurs in flowers.

Heat is a consequence of germination; the temperature is also augmented during flowering, as has been proved by Theodore de Saussure in the Arum, the Gourd, the Bignonia radicans, Polyanthes tuberosa, and others.

The greater part of the saccharine matter produced during germination is absorbed by the radicle, and transmitted to the first bud of the young plant. Dunal is of opinion that the sugar of the nectary and petals is, in like manner, conveyed to the anthers and young ovules; and that the free liquid honey, which exists in such abundance in many flowers, is a secretion of superabundant fluid; it can be taken away, as is well known, without injury to the flower.

This opinion will probably be considered the better founded, if it can be shown that the disengagement of caloric and destruction of oxygen are in direct relation to the development of the glandular disc, and also are most considerable at the time when the functions of the anthers are most actively performed.

In no plants, perhaps, is the glandular disc more developed than in Arums; and it is here that the most remarkable

degree of development of caloric has been observed. Senebier found that the bulb of a thermometer, applied to the surface of the spadix of Arum maculatum, indicated a temperature 7° higher than that of the external air. Hubert remarked this, in a still more striking degree, upon Arum cordifolium, at the Isle of France. A thermometer placed in the centre of five spadixes stood at 111°, and in the centre of twelve at 121°, although the temperature of the external air was only 66°. The greatest degree of heat in these experiments was at sunrise. The same observer found that the male parts of six spadixes, deprived of their glandular part, raised the temperature only to 105°; and the same number of female spadixes only to 86°; and, finally, that the heat was wholly destroyed by preventing the spadix from coming in contact with the air.

Similar observations were made by others, with corresponding results; but, nevertheless, as many persons attempted in vain to witness the phenomenon, it began to be doubted, especially after Treviranus added his authority to that of those who doubted the existence of any disengagement of heat. The truth of the statement of Saussure and others has lately, however, been placed beyond all further doubt, by the experiments of Adolphe Brongniart upon Colocasia odora. (*Nouv. Ann. du Muséum*, vol. iii.) From the period of the expansion of the spathe, he applied to the middle of the spadix a very delicate and small thermometer, which he fixed to its place by a piece of flannel rolled several times round it and the spadix, so that the bulb of the thermometer touched the spadix on one side; and on all others was protected by the flannel from contact with the air. All this little apparatus covered so small a portion of the spadix, that it was left in its place without interfering with the functions of that part. On the 13th of March, the spathe not being open, the flower diffused, notwithstanding, a fragrant smell. On the 14th it was open, and the odour was much increased. The emission of pollen took place on the 16th, between 8 and 10 A.M., and continued till the 18th. On the 19th the flower began to fade. From the 14th to the 19th the temperature increased daily, during the night and in the

morning falling back to nearly that of the surrounding air. The maximum of elevation of temperature above that of the atmosphere occurred—

On the 14th, at	3 P.M.	4·5° centigrade
15th,	4 P.M.	10°
16th,	5 P.M.	10·2°
17th,	5 P.M.	11°
18th,	11 A.M.	8·2°
19th,	10 A.M.	2·5°

These maxima might be almost compared to the access of an intermittent fever.

Vrolik and Vriese consider the so called Arum cordifolium of the Isle of France to be the same as the aforesaid Colocasia odora, upon whose temperature they made very numerous hourly observations in the Botanical Garden of Amsterdam, the result of which was, that the maximum of difference observed between the temperature of the spadix and that of the green-house amounted to 10° centig. (*Ann. des Sc.* vol. v. 145.) Göppert adds that plants are generally warmer than the air which surrounds them. (*Ueber warme Entwickelung in der lebenden Pflanze.* Wien, 1832.)

That these phenomena should not be observed in ordinary cases, is no proof that they do not also occur; for it is easy to comprehend that, when flowers are freely exposed to the external air, the small amount of caloric which any one may give off will be instantly dispersed in the surrounding air, before the most delicate instrument can be sensible of it; and that it is in those instances only of large quantities of flowers collected within a hollow case, like a spathe, which prevents the heat escaping when evolved, that we can hope to measure it.

From experiments of Saussure, it seems certain that the disengagement of heat, and, consequently, destruction of oxygen, is chiefly caused by the action of the anthers, or at least of the organs of fecundation, as appears from the following table :—

Names.	Duration of the Experiment.	Oxygen destroyed.		
		By the bud.	By the flower during its expansion.	By the flower in withering.
Passiflora serratifolia .	12 hours.	6 times its vol.	12	7
Hibiscus speciosus . .	24 „	6 „	8·7	7
Cucurbita maxima, male flower . .	24 „	7·4 „	12	10
Arum italicum, spadix cold . . .	24 „	5 to 6 „		
spadix hot . . .	. . . . .	. . . . .	30	
24 hours after . .	. . . . .	. . . . .	. . . . .	5

It was also found that flowers in which the stamens, disc, pistil, and receptacle, only were left, consumed more oxygen than those that had floral envelopes, as is shown by the following table:—

Species.	Duration of the Experiment.	Oxygen destroyed.	
		By the flowers entire.	By the usual organs only.
Cheiranthus incanus . .	24 hours.	11·5 times their vol.	18 times their vol.
Tropæolum majus . .	24 „	8·5 „	16·3 „
Cucurbita maxima, male	10 „	7·6 „	16 „
Hypericum calycinum .	24 „	7·5 „	8·5 „
Hibiscus speciosus . .	12 „	5·4 „	6·3 „
Cobæa scandens . . .	24 „	6·5 „	7·5 „

And it is here to be noticed, that those whose sexual apparatus destroyed the most oxygen have the greatest quantity of disc, and *vice versâ;* with the exception of Cobæa scandens, in which the disc is very firm and persistent, and probably, therefore, acts very slowly.

When the cup-shaped disc of the male flowers of the Gourd was separated from the anthers, the latter only consumed 11·7 times their volume of oxygen, in the same space of time which was sufficient for the destruction of sixteen times their volume when the disc remained. The spathe of Arum maculatum consumed, in twenty-four hours, five times its volume of oxygen; the termination of the spadix thirty times; the sexual apparatus 132 times, in the same space of time.

An entire Arum Dracunculus, in twenty-four hours, destroyed thirteen times its volume of oxygen; without its spathe fifty-seven times; cut into four pieces, its spathe destroyed half its volume of oxygen; the terminal appendix twenty-six times; the male organs 135 times; the female organs ten times.

The same ingenious observer also ascertained that double flowers, that is to say, those whose petals replace sexual organs, vitiate the air much less than single flowers, in which the sexual organs are perfect.

Is it not then, concludes Dunal, probable, that the consequence of all these phenomena is the elaboration of a matter destined to the nutriment of the sexual organs? since the production of heat and the destruction of oxygen are in direct relation to the abundance of glandular surface, and since these phenomena arrive at their maximum of intensity at the exact period when the anthers are most developed, and the sexual organs in the greatest state of activity.

"To the above facts," says Dumas, "several valuable remarks have been added by the Dutch *savants*, which serve to complete the study of this curious phenomenon. They found that the temperature of the flower rose as high in oxygen gas as in air, whilst in nitrogen nothing similar could be observed. They have also shown that in proportion as the temperature rises, in the same proportion is carbonic acid formed. In a word, they found all the characters of combustion, in this phenomenon, and they did not hesitate so to state it. It may be affirmed, then, that in Colocasia odora, there is, every day during fecundation, a considerable rise of temperature, owing to the combustion of carbon, by which a large quantity of carbonic acid is formed, and an intense odour produced, which seems connected with this phenomenon of combustion."

These observations have been confirmed by Dutrochet by thermo-electrical experiments, of which the following account is given by Meyen:—He says, plants possess a peculiar warmth; but it is completely absorbed by the evaporation of the sap, by the evolution of oxygen by day, and of carbonic acid by night. It rather seems that, in the natural

state, plants possess the property of producing cold, for they almost always have a lower temperature than that of the surrounding air. If, however, evaporation is prevented, it is easy to observe the proper temperature of plants; Dutrochet used a thermo-electrical apparatus, and for comparison the experiments were made both with living and dead plants; dead plants acquired the temperature of the surrounding medium; live plants the same, with the addition of that which was lost by evaporation, and which M. Dutrochet reckons at the most to be $\frac{1}{4}^{\circ}$ Cels; often only $\frac{1}{6}^{\circ}$, or even $\frac{1}{10}$ or $\frac{1}{12}^{\circ}$. The proper heat of young twigs and leaves vanishes in the night, or in general in the dark, and appears again under the influence of light. The higher the external temperature, the greater is the vegetable warmth. That part of the heat of plants which is carried off by the evolution of oxygen cannot be determined quantitatively.

Proofs that plants possess a peculiar heat, dependent upon their vital forces, was long since published in Germany; and in my "Physiology," says Meyen, I proved that an extrication of heat occurs not only in germinating seeds, and in the fresh fruits of Areca Catechu when lying together, but also in leaves and herbage in general; "singly they do not exhibit any warmth on account of the evaporation, but they do when brought together in masses. I convinced myself of the truth of this by the thermometer. I have several times experimented with fresh-cut grass and fresh spinach leaves. Dutrochet has added that new researches confirm the former ones. In the stem of Euphorbia Lathyris he remarked the vegetable heat amount to $\frac{1}{3}^{\circ}$ C., but only so long as it was in a verdant state. He also found heat in roots, fruits, and even embryos. Complete exclusion of light totally prevents the rise and fall of temperature, but this does not always take place the first day. M. Dutrochet remarked the change of temperature by night and by day even on the second day of the experiment."

"MM. Bergsma and Van Beck have clearly proved that perspiration is the cause of the difficulty in measuring the temperature proper to plants. They chose (in January, 1839) a hyacinth growing in a glass for their experiments.

The glass was put into another vessel, containing water of a higher temperature, in order in this manner to increase the activity of the roots. The needles of the thermo-electrical apparatus were then inserted into the external parts of the flower-stalks, and instead of an increase of temperature, they observed a fall; the apparatus indicated 17·5° C., while that of the water was 28·5°. The experiment was repeated several times with like success, as also with the flower-stalk of Entelea arborescens. This was owing to the powerful perspiration caused by increased activity promoted by warm water. When the needles were inserted into the middle of the flower-stalk of the hyacinth, the temperature of the interior was found to be 1° higher than that of the surrounding air.

At a later period M. Dutrochet published some further observations, and stated generally that plants possess a peculiar heat, which is principally located in the green parts. This heat exhibits a daily periodicity; it reaches its maximum towards mid-day, and its minimum during the night. The hour at which plants reach their maximum temperature is the same for each species, but different in different species; thus, Rosa canina at 10 a.m.; Allium Porrum at 11 a.m.; Borago officinalis at mid-day; Euphorbia Lathyris at 1 p.m.; Sambucus nigra at 2 p.m.; and Asparagus and Lactuca sativa at 3 p.m. The greatest heat is in the neighbourhood of the principal bud, and in woody plants often only in the green extremities. Other experiments confirm the fact, that plants growing in the dark lose their vegetable heat; but experiments on different fungi showed that these also possess a daily periodicity. Boletus æneus exhibited a heat of $\frac{1}{2}$° C.

CHAPTER IX.

FERTILISATION.—HYBRID PLANTS.

The office of the stamens is to produce the matter called pollen, which has the power of fertilising the pistil through its stigma. The stamens are, therefore, the representatives, in plants, of the male sex, the pistil of the female sex.

The old philosophers, in tracing analogies between plants and animals, were led to attribute sexes to the former, chiefly in consequence of the practice among their countrymen of artificially fertilising the female flowers of the date with those which they considered male, and also from the existence of a similar custom with regard to figs. This opinion, however, was not accompanied by any distinct idea of the respective functions of particular organs, as is evident from their confounding causes so essentially different as fertilisation and caprification; nor was it general, although Pliny, when he said that "all trees and herbs are furnished with both sexes," may seem to contradict this statement; at least, he indicated no particular organs in which the sexes resided. Nor does it appear that more distinct evidence existed of the universal sexuality of vegetables till about the year 1676, when it was for the first time clearly pointed out by Sir Thomas Millington and Grew. Claims are, indeed, laid to a priority of discovery over the latter observer by Cæsalpinus, Malpighi, and others; but I see nothing so precise in their works as we find in the declaration of Grew, "that the attire (meaning stamens) do serve as the male for the generation of the seed." It would not be consistent with the plan of this work, to enter into any detailed account of the gradual advances which such opinions made in the world, nor to trace the progress of discovery of the precise nature of the several parts of the stamens and pistil. Suffice it to say, that, in the hands of Linnæus,

the doctrine of the sexuality of plants seemed finally established, never again to be seriously controverted; for it must be admitted, that the denial of this fact, which has been since occasionally made by such men as Alston, Smellie, and Schelver, has carried no conviction with it. It is a general law that the powder which is contained in the case of the anthers, and which is called pollen, must come in contact with the viscid surface of the stigma, or no fecundation can take place. It is possible, indeed, without this happening, that the fruit may increase in size, and that the seminal integuments may even be greatly developed; the elements of all these parts existing before the action of the pollen can take effect: but, under such circumstances, whatever may be the development of either the pericarp or the seeds, no embryo can be formed. This universality of sexes does not, however, extend to cryptogamic plants, as has been already shown.

In order to insure the certain emission of the pollen at the precise period when it is required, a beautiful contrivance is provided. Purkinje has demonstrated the correctness of Mirbel's opinion in 1808, that the cause of the dehiscence of the anther is its lining, consisting of cellular tissue, cut into slits, and eminently hygrometrical. He shows that this lining is composed of cellular tissue, chiefly of the fibrous kind, which forms an infinite multitude of little springs, that when dry, contract and pull back the valves of the anthers, by a powerful accumulation of forces, individually scarcely appreciable; so that the opening of the anther is not a mere act of chance, but the admirably contrived result of the maturity of the pollen; an epoch at which the surrounding tissue is necessarily exhausted of its fluid, by the force of endosmose exercised by each particular grain of pollen.

That this exhaustion of the circumambient tissue by the endosmose of the pollen is not a mere hypothesis, has been shown by Mirbel in a continuation of the memoir I have already so often referred to. He finds that, on the one hand, a great abundance of fluid is directed into the cells in which

the pollen is developed, a little before the maturity of the latter, while, by a dislocation of those cells, the pollen loses all organic connexion with the lining of the anther; and that, on the other hand, these cells are dried up, lacerated, and disorganised, at the time when the pollen has acquired its full development.

In some plants, especially in Bellworts (Campanulaceæ), a provision is found for brushing the pollen out of the anthers and conveying it to the stigma; concerning which we have the following observations by M. Adolphe Brongniart:—

"It has long been known that the external surface of the upper part of the style, and of the stigmatic arms of Campanulaceous plants, is covered with long hairs, which are very visible in the bud, before the dispersion of the pollen, and which are regularly arranged in longitudinal lines in direct relation to the number and position of the anthers.

"These hairs and their connexion with the pollen, at first remarked by Conrad Sprengel in several species of Campanula, and afterwards by Cassini, with more care, in Campanula rotundifolia, have been observed by M. Alphonse De Candolle in the whole Campanulaceous order, with the exception of the small genus Petromarula. At the period of dehiscence of the anthers, before the expansion of the corolla, and when the arms of the style are still pressed against each other in the form of a cylinder, these hairs cover themselves with a considerable quantity of pollen, which they brush, so to speak, out of the cells of the anther; and for this reason they have been named, like the analogous hairs in Compositæ, Collectors.

"At the period when the flower expands, the arms of the style, or stigmata separate, and curve backwards, and the anthers that surround them retire and shrivel up, after having lost all their pollen; but at the same time the pollen, which was deposited on the outside of the style, detaches itself, and the hairs that covered the surface disappear.

"This led Cassini to call these hairs deciduous, and to say that they disappear at the same time with the pollen which they retained. There then remains, he says, upon the style, nothing more than little asperities."

M. Alphonse De Candolle is yet more explicit. He expresses himself thus :—"the arms of the style begin to diverge. At the same time the pollen disappears, the collecting hairs drop off, and the style becomes altogether smooth." Nevertheless, a microscopical examination of these hairs has satisfied me that they do not fall off, but that they offer a phenomenon of which I know no other example in the vegetable kingdom. They are retractile, like the hairs of certain Annelids, or the tentacula of snails.

If we examine a thin longitudinal slice of a young style, before the emission of the pollen, it is seen that these cylindrical hairs, a little tapering to their fine extremity, are formed by an external lengthening of the epidermis, and that they are perfectly simple, without articulation or partitions even at their base.

Immediately below the base of each hair, there exists in the subjacent cellular tissue a cavity about equal in depth to half or a third the length of the hair, continuous with its cavity, and apparently filled with the same fluid. This cavity, however, does not extend beyond the most superficial stratum of the style or stigma, and has no relation to the tissues situated deeper, of which mention will be made presently. This arrangement is preserved up to the time of the expansion of the flower, the hairs being at that time covered by grains of pollen, applied over their surface, and held between their interstices.

But at this period the hairs retract into the cavities formed at their base among the cellular tissue; the terminal half ensheaths itself in the half situated next the base, as it by degrees returns into the cavity. The point only of the hair remains projecting beyond the surface of the style, and causes the asperities noticed by Cassini. Sometimes the hair, in retracting thus within itself, draws with it a few grains of pollen, which thus appear to penetrate the tissue of the style, but which, in fact, are always on the outside of the hair. With care these hairs may be pulled out again by the point of a needle, and then the pollen-grains which appear to have penetrated the style are immediately expelled. Such pollen-grains undergo no change during their application to the

collecting hairs, nor even when they are drawn inwards by the latter during their act of retraction.

There is, therefore, no communication between them and the interior of the style.

As to the immediate cause of this retraction of the hairs, without pretending to give a certain explanation of it, I think it may be ascribed to the absorption of the liquid contained both in the hair and in the cavity at its base, an absorption, the effect of which will be to pull back the hair into the cavity, at least I see no other part whose action can produce the phenomenon.

An examination of the structure of the external stratum of the style and stigmatic arms, has already tended to show the baseless character of the opinion held by those physiologists who think that fertilisation can take place by the action of the pollen upon this part; an opinion offered with doubt by Cassini and Alphonse De Candolle, asserted, on the contrary, in the most positive manner, by Treviranus, who, in his *Physiology*, vol. ii. p. 343, considers the internal stigmatic surface to be formed of papillæ analogous to those which sometimes terminate the petals, while, according to him, the hairs covering the external surface of the style and stigma, perform the part of the stigmata. Link (*Philosophia Botanica*, 2nd edition, vol. ii. p. 222), also admits that fertilisation takes place by these hairs, whose points, he says, are destroyed while the base remains, and so present a large opening which leads into the style.

We therefore see that the most distinguished botanists entertain opinions either doubtful or contrary to the most probable analogies. Nevertheless, in dissecting the true stigma of Campanulas, that is to say, the inner face of the stigmatic arms, after their divergence, we find that the grains of pollen scattered over the surface adhere to it, as to all true stigmas, first by aid of the fluid that lubricates them, and finally, by the production of pollen-tubes which penetrate it, and soon mark a cord of long soft vesicular tissue, which occupies the centre of the style.

This cord of conducting tissue, of hexagonal form, in the true Campanulas, whose stigma has three arms, is perfectly

distinct from the surrounding tissue, much more dense, and coloured; it is easily separated, and is entirely composed of vesicles of a cylindrical or somewhat fusiform figure, very long, colourless, quite separate at the sides, articulated to each other, end to end, and containing very small regular globules of starch, becoming blue upon the application of iodine. The pollen-tubes which penetrate between the utricles of this tissue are easily distinguished by being much finer, unarticulated, and filled with very fine indistinct granules." (*Annales des Sciences.*)

Morren has made some statistical observations upon the sexual organs of Cereus grandiflorus. He found that in each flower of this plant there are about 500 anthers, 24 stigmata, and 30,000 ovules. He estimates each anther to contain 500 grains of pollen; the whole number in each flower being 250,000; so that not more than an eighth of the whole number of pollen grains can be supposed to be effective. The distance from the stigma to the ovules he computes at 1150 times the diameter of the pollen grain.

The exact mode in which the pollen took effect was for a long time an inscrutable mystery. It was generally supposed that, by some subtle process, a material vivifying substance was conducted into the ovules through the style; but nothing certain was known upon the subject until the observations of Amici and of Adolphe Brongniart had been published. It is now ascertained, that, a short time after the application of the pollen to the stigma, each grain of the former emits one or more tubes of extreme tenuity, not exceeding the 1500th or 2000th of an inch in diameter, which pierce the conducting tissue of the stigma, and find their way down to the region of the placenta, including within them the molecular matter found in the pollen grain. These pollen-tubes actually reach the ovules. Brown states he has traced them into the apertures of those of Orchis Morio, and Peristylus (Habenaria) viridis, although this great observer adds that the tubes in those plants probably do not proceed from the pollen.

Be this as it may, it seems certain that it is necessary for

the pollen to be put in communication with the foramen of the ovule, through the intervention of the conducting tissue of the style. In ordinary cases this is easily effected, in consequence of the foramen being actually in contact with the placenta. Where it is otherwise, nature has provided some curious contrivances for bringing about the necessary contact. In Euphorbia Lathyris the apex of the nucleus is protruded far beyond the foramen, so as to lie within a kind of hood-like expansion of the placenta: in all campylotropal ovules the foramen is bent downwards, by the unequal growth of the two sides, so as to come in contact with the conducting tissue; and in Statice Armeria, Daphne Laureola, and some other plants, the surface of the conducting tissue actually elongates and stops up the mouth of the ovule, while fertilisation is taking effect. A different arrangement occurs in Helianthemum. In plants of that genus the foramen is at the end of the ovule most remote from the hilum; and although the ovules themselves are elevated upon cords much longer than are usually met with, yet there is no obvious means provided for their coming in contact with any part through which the matter projected into the pollen-tubes can be supposed to descend. It has, however, been ascertained by Adolphe Brongniart, that, at the time when the stigma is covered with pollen, and fertilisation has taken effect, there is a bundle of threads, originating in the base of the style, which hang down in the cavity of the ovary, and, floating there, convey the influence of the pollen to the points of the nuclei. So, again, in Asclepiads. In this tribe, from the peculiar conformation of the parts, and from the grains of pollen being all shut up in a sort of bag, out of which there seemed to be no escape, it was supposed that such plants must at least form an exception to the general rule. But before the month of November, 1828, the celebrated Prussian traveller and botanist, Ehrenberg, had discovered that the grains of pollen of Asclepiads acquire a sort of tails, which are all directed to a suture of their sac on the side next the stigma, and which at the period of fertilisation are lengthened and emitted; but he did not discover that these tails are only formed subsequently to the commencement of a new vital

action connected with fertilisation, and he thought that they were of a different nature from the pollen-tubes of other plants: he particularly observed in Asclepias syriaca that the tails become exceedingly long, and hang down.

In 1831, the subject was resumed by Brown in this country, and by Adolphe Brongniart in France. These two distinguished botanists ascertained that the production of tails by the grains of the pollen was a phenomenon connected with the action of fertilisation; they confirmed the existence of the suture described by Ehrenberg; they found that the true stigma of Asclepiads is at the lower part of the discoid head of the style, and so placed as to be within reach of the suture through which the pollen-tubes or tails are emitted; they remarked that the latter insinuated themselves below the head of the style, and followed its surface until they reached the stigma, in the tissue of which they buried themselves so perceptibly, that they were enabled to trace them, occasionally, almost into the cavity of the ovarium; and thus they established the highly important fact, that this family, which was thought to be one of those in which it was impossible to suppose that fertilisation takes place by actual contact between the pollen and the stigma, offers the most beautiful of all examples of the exactness of the theory, that it is at least owing to the projection of pollen-tubes into the substance of the stigma. In the more essential parts these two observers are agreed: they, however, differ in some of the details, as, for instance, in the texture of the part of the style which I have here called stigma, and into which the pollen-tubes are introduced. Brongniart both describes and figures it as much more lax than the other tissue; while, on the other hand, Brown declares that he has in no case been able to observe "the slightest appearance of secretion, or any differences whatever in texture between that part and the general surface of the stigma" (meaning what I have described as the discoid head of the style).

I have remarked that, in Morrenia odorata, an Asclepiad, the emission of tubes takes place to such an extent as to give the head of the stigma altogether the appearance of a mass of tow. (See *Botanical Register*, 1838, Misc. No. 129.)

The first act of fecundation in plants is, therefore, usually the emission of a tube by a pollen grain; but the impregnation of the ovule must necessarily be a subsequent and perhaps different process, in consequence, among other things, of the distance which the pollen tube must travel through the stigmatic tissue before it reaches the ovule; a distance computed by Morren to amount to 1150 times its own diameter in Cereus grandiflorus. This botanist states that, in that plant and the Vanilla impregnation does not in fact occur till some weeks after contact between the pollen and stigma has taken place.

It is, however, worthy of remark, that the first act of fecundation produces an immediate effect upon the floral envelopes. In Orchids, a flower artificially fecundated will change colour and begin to fade in twenty-four hours at the latest after this has happened, although the same flower would have remained in beauty many days if not impregnated.

It would, therefore, seem that actual contact between the pollen and the stigma is indispensable in all cases. Orchids have, however, been thought to offer an exception; for in those plants nature has, on the one hand, provided special organs, in the form of the stigmatic gland and the caudicle of the pollen masses, to assist in the act of fertilisation; and on the other appears to have taken great precautions to prevent contact, by so placing the anther that it seems next to impossible for the pollen to touch the stigma unless artificially applied to it. Nevertheless, it is represented by Adolphe Brongniart, in a paper read before the Academy of Sciences at Paris, in July, 1831, that contact is as necessary in these plants as in others, and that, in the emission of pollen tubes, they do not differ from other plants. These statements have been followed up by Brown, in an elaborate essay upon the subject, in which the results that are arrived at by our learned countryman are essentially to the same effect. On the other hand, the observations of Francis Bauer, and the general structure of the order, seemed at variance with the probability of actual contact being necessary; and, as Brown was obliged to have recourse to the supposition that the pollen of many of these plants must be actually carried by insects

from the boxes in which it is naturally locked up, it seemed that the mode of fertilisation in Orchids was still unsettled; and it must be admitted that the agency of insects, to which Brown had recourse in order to make out his case, was scarcely reconcileable with his supposition that the insect forms, which in Ophrys are so striking, and which, he says, resemble the insects of the countries in which the plants are found, "are intended rather to repel than to attract." But although such arguments were not unobjectionable, it is, nevertheless, certain that Orchids require contact to take place between their pollen and stigma, in order to insure fertilisation. This has been shown by Professor Morren, and has now become in gardens a matter of notoriety.

Conflicting statements as to what really occurs when the embryo is first generated in the amniotic sac, have for several years occupied the attention of Botanists. To enter into any discussion of the respective value of these statements would be less advantageous to the student than the record of the observations actually made by excellent and trustworthy observers. The real phenomena are explained in the following cases, described by botanists familiar with the microscope and expert in anatomical examination.

In the nineteenth volume of the *Linnæan Transactions*, Dr. Herbert Giraud has published the following very detailed account of facts observed by him in Tropæolum majus, a plant whose parts present peculiar facilities for examination. They are arranged under seven general heads, corresponding with as many progressive periods in the growth of the so-called female organs, extending from the completion of the anatropal development of the ovule, to the perfect formation of the embryo: or from the commencement of the expansion of the bud, to the complete formation of the fruit.

"*First Period.*—On making a section of a carpel (just before the expansion of the bud), from its dorsum inwards towards the axis of the pistil, and in the direction of that axis, the solitary ovule is at the same time divided, and is found to have completed its anatropous development. Continuous with that part of the columella which forms the

placenta, is a portion of rather firm and dense cellular tissue, inclosing a bundle of vessels, and forming the so-called umbilicus: this, with the vessels it incloses, descends in apposition with the placenta to form the raphe, and near the point where it terminates in the base of the ovule, the vessels are gradually lost, or rather terminate in closed extremities. The nucleus has only one tegumentary membrane (primine ?) at the apex of which is presented the exostome, or micropyle, opening close by, and to the outside of the umbilicus: so that the direction of the nucleus is exactly parallel with that of the axis of the pistil. The conducting tissue of the style may be traced between the columella, and that prolongation of the carpellary leaf which forms the style into the carpellary cavity, as far as the exostome, with which it is brought in contact by the anatropous development of the ovule. The vessels which proceed along the placenta to form the raphe, are spiral vessels and annular ducts; and at the point at which they make a turn downwards towards the chalaza many of them end in closed extremities, while the vascular structure of the raphe usually terminates in a single vessel. These vessels, together with an analogous set which run along the dorsum of the carpel, proceed from a larger bundle of vessels, which in the receptacle bifurcates into these two sets.

Second Period.—During the expansion of the bud, before the dehiscence of the anther, and, therefore, before impregnation, a small elliptical cavity appears near the apex of the nucleus, having a delicate lining membrane formed by the walls of the surrounding cells. This cavity is the embryo-sac ('sac embryonnaire,' Brongniart and F. G. F. Meyen; 'membrana amnii,' Malpighi; 'quintine,' Mirbel.) From the exostome a minute canal may be traced in the apex of the nucleus, leading to the embryo-sac. The apex of the embryo-sac incloses, at this period, a quantity of organisable mucilage, containing many minute bodies having the appearance and character of cytoblast (Schleiden.)

Third Period.—The apex of the nucleus, and of its tegumentary membrane, is now inclined and approximated towards the axis of the pistil. The embryo-sac is much enlarged and lengthened; its mucilage has disappeared; and in its place

there is formed an elongated diaphanous utricle (primary utricle; 'utricule primordiale,' Mirbel; 'vésicule embryonnaire,' F. G. F. Meyen; 'l'extrémité antérieure du boyan pollinique,' Schleiden) containing a quantity of globular matter ('globulocellular cambium,' Mirbel; 'cytoblasts,' Schleiden). This primary utricle is developed wholly within the embryo-sac, from which it can be clearly seen to be distinct.

Fourth Period (after impregnation has occurred).—The pollen tubes do not extend into the carpellary cavity; but the fovilla, with its granules, is found abundantly in the passage leading from the style to the exostome. With the increased development of the embryo-sac, the primary utricle, as it elongates, becomes distinctly cellular, by the development of minute cells in its interior, while at the extremity, next the base of the nucleus, it is terminated by a spherical extremity, consisting of numerous globular cells. The primary utricle, at this period, assumes the character of the suspensor (Mirbel); and its spherical extremity constitutes the first trace of the embryo.

Fifth Period.—At this stage the apex of the nucleus, with that of its tegumentary membrane, becomes directed more towards the axis of the pistil. The spherical extremity of the suspensor enlarges, and almost entirely fills the cavity of the embryo-sac; and it now becomes more evident that it constitutes the axis of the embryo. The suspensor is, in a corresponding degree, lengthened by an increase in the number and size of its cells; while its upper extremity has now protruded through the apex of the embryo-sac, the apex of the nucleus, and through the micropyle. From this extremity there is a considerable development of cells, many of which hang loosely in the passage leading to the conducting tissue of the style, while others unite in forming a process which passes round the outside of the ovule into the carpellary cavity, and between the inner surface of the carpel and the outer surface of the ovule. This process of cellular tissue is composed of from nine to twelve rows of cells; its extremity resembles in appearance, and in the anatomical condition of its cells, the spongiole of a root. When the ovule is removed

from its carpel, and slight traction is made upon this cellular process, the suspensor, with the embryo, may be withdrawn from the embryo-sac, through the exostome and apex of the nucleus; thus proving the perfect continuity of this cellular process with the suspensor, and through it with the embryo itself.

Sixth Period.—The suspensor is now more attenuated, consisting only, as at first, of two rows of cells; the cellular process, with which it is organically united, has reached the base of the ovule; the cells of its extremity abound in cytoblasts, showing it to be yet progressing in its development. With the increased growth of the embryo two lateral processes are observed proceeding, on opposite sides, from the axis and evidently forming the first traces of the cotyledons.

Seventh Period.—All distinction between the nucleus and its tegumentary membrane ceases, as they are now united in one envelope inclosing the embryo-sac. The cellular process connected with the suspensor has become so much developed, that its extremity has passed around the base of the ovule and is directed towards the axis of the pistil. The lateral processes of the axis of the embryo have become distinct fleshy cotyledons extending backwards from their point of origin towards the radicle, as well as forwards in the direction of the plumule; both which organs they inclose in corresponding depressions in their opposed surfaces. With the development of the radicle towards the exostome, the opposite extremity of the axis of the embryo (in the form of the plumule) extends towards the base of the nucleus, but is still inclosed in the depression formed in the concavity of the cotyledons.

The subsequent changes consist chiefly in the great development of the cotyledons, which ultimately come to occupy the whole cavity of the nucleus, filling the space usually taken up by the albumen."

Upon these facts Dr. Giraud observes, that the physiological inferences deducible from them contribute to the determination of many unsettled points involved in the theory of vegetable embryogeny, and serve to elucidate many obscurities relating to the morphology of the embryo.

"It has been shown," he proceeds, "that the formation of the embryo-sac, and the development of cytoblasts within it, takes place at a period prior to the impregnation of the pistil; and that even the primary utricle itself makes its appearance before the emission of the pollen from the anther, and before the expansion of the stigma; so that the origin of the primary utricle must not be referred to the influence of impregnation, as has been already pointed out by Mirbel and Spach in the case of Zea Mays. (See their paper in the *Annals of Natural History*, v. 228.) At its first appearance the primary utricle is seen to be quite distinct from the embryo-sac, even at its apex, with which, however, it is brought in contact at a subsequent period, and ultimately even penetrates that membrane; so that, in this instance at least, the primary utricle cannot result from a depression or involution of the embryo-sac, as is maintained by Adolphe Brongniart. After the expansion of the lobes of the stigma and its impregnation, the pollen-tubes may be traced in the conducting tissue of the style, but not so far as the micropyle: in the channel, however, leading to this point, the pollen-granules are found in abundance, and are doubtless brought in contact with the outer surface of the embryo-sac through the exostome and the minute canal in the apex of the nucleus. At this period the first trace of the embryo appears in the formation of the spherical body at the inferior extremity of the primary utricle, which has now assumed the character of the suspensor (umbilical cord). Hence, then, we are led to consider the origin of this simple spherical body, which is ultimately transformed into the embryo, as resulting from a peculiar process of nutrition, determined by the material or dynamic influence of the fovilla, conveyed through the medium of the primary utricle or suspensor. As it is through that organ that the embryo appears to derive its nourishment during the period of its development, we should from this function, as well as from its anatomical relations, consider the suspensor as the true umbilical cord; the medium of connection, therefore, between the ovule and the columella (or so-called placenta) ought not to receive the name of

umbilical cord or funiculus, which terms it would be well to confine to the suspensor alone; while the former might retain the appellation of podosperm as referring to its relation to the ovule.

"As it is necessary that an umbilical cord should be organically united with the embryo, the impropriety of considering the organ described by Malpighi in that light will become sufficiently obvious. This structure consists of a minute cellular process extending from the base of the embryo-sac to the base of the nucleus, and has been found chiefly in the Cucurbitaceæ and Rosaceæ. It appears, however, to be but a mere appendage of the embryo-sac, from which it takes its origin, and often never reaches the base of the nucleus, and therefore cannot be the medium of nutrition even to the embryo-sac. To this organ, therefore, it would be better to confine the term applied to it by Dutrochet, and name it the *hypostate*, as pointing out merely its anatomical relations. The cellular process proceeding from the extremity of the suspensor, next the exostome, around the outer surface of the ovule into the carpellary cavity is an organ of somewhat unusual occurrence, but from its mode of growth and structural relations, it may be inferred to be of very essential importance to the origin and development of the embryo. Now it has been recently pointed out by F. G. F. Meyen, that in the great majority of instances the pollen-tube, after having penetrated the micropyle, is brought in contact with the apex of the embryo-sac, with which it there contracts an adhesion; from this period the changes consequent on impregnation date their commencement; and, under the direct influence of this immediate application of the fovilla to the embryo-sac, continue with uninterrupted regularity. But in the case of Tropæolum majus, as the pollen-tube never reaches the embryo-sac, some additional means are required to insure that influence of the fovilla on the primary utricle which is necessary for the development, at its extremity of the spherical cellular body, which subsequently becomes the embryo. This action, then, is effected by the projection of this cellular process from the primary utricle, which, by being immersed (so to speak) in the fovilla, is made the medium

for the transmission of the latter to the primary utricle, and through it to the embryo itself; for which office the structure of its extremity (so like a spongiole) renders it peculiarly fitted.

"It may now," concludes Dr. Giraud, "be shown how far the foregoing observations bear upon the undetermined question of the origin of the embryo. That in this plant the primary utricle and the future embryo never have any structural connexion with the extremity of the pollen-tube at their first origin, or at any subsequent period of their development, is sufficiently obvious from the fact, that the pollen-tube is never brought into contact with the embryo-sac. As the primary utricle makes its appearance before impregnation has occurred, it cannot be possible that that organ has ever formed the extremity of the pollen-tube, as is believed to be the case by Schleiden and Wydler. Moreover, as the primary utricle takes its origin wholly within the embryo-sac, and at the earliest period of its formation is not in contact with that membrane, it cannot have been formed by the pollen-tube pressing before it a fold of the embryo-sac in its passage into the cavity of that structure, as Schleiden has maintained."

Griffith is equally opposed to the opinion of Schleiden, as to the action of the end of a pollen tube on the sac of the embryo. His paper in the *Transactions of the Linnæan Society*, vol. xix., from which I make a few extracts, will well repay the most careful perusal.

"The first process in the development of the seed, subsequently to the penetration or application of the boyan to the embryo-sac, would in Santalum, Osyris, Loranthus, and Viscum, appear to consist of the formation of cellular tissue. This may be applied, I believe, to most if not to all instances. This cellular tissue appears to have two different origins; one, and this is the earliest in development, being, perhaps, referable to the embryo-sac, while the other appears directly referable to the anterior ends of the pollen tubes.

"In no instance, perhaps, where the embryo is developed from the ends of the pollen tubes, does it become developed so immediately that no cells intervene between it and the end of the pollen tube; this is particularly evident during the

earlier stages of development. That part of the embryo in which the condensed tissues occur, and which, from its appearance and frequent tendency to constriction round its base, I at first suspected was the only part of the embryo (the rest being then funiculus), corresponds, I think, in situation with the collet; it is very evidently not the point of the radicle, for this will subsequently be found so close to the vesicle as to authorise me in assuming that the greater part of the soft cellular tissues becomes the body of the root.

"None of my observations have tended to confirm his (Schleiden's) idea of the inflection of the embryo-sac before the pollen tube; and it appears to me sufficiently obvious, that if such were the case, the cylindrical bag constituting the 'embryo in its first stage of development,' would consist of three membranes or layers: viz., the first or outer, of the ordinary and uninflected membrane of the sac; the second, of its inflected portion; the third, of that of the pollen tube itself."

M. Schleiden assumes the applicability of his conclusion, drawn from direct observation in several plants, to all others in which direct observation is more difficult, on three distinct grounds, the first of which, regarding the diameter of the tube outside the sac and just within it, is, I cannot but think, of very minor importance, neither does it present itself in Santalum; the second, which would confine certain peculiar contents to the pollen tube, appears to me contradicted by Santalum and Loranthus; and the third, which positively refers plurality of embryos to a plurality of pollen tubes, is contradicted in a most marked manner by Loranthus.

In the Ray Reports we have the following translation of Link's remarks upon the observations made by M. Decaisne upon the Miseltoe; a very anomalous plant:—

"On examining the ovary in its earliest state, it presents a uniform mass, with two small interruptions of the cellular tissue; the cells, however, soon unite again, in order to form a clear cellular tissue in the centre, surrounded by a green circle. No ovule is perceived in the ovary for a long time, not as far as the commencement of June, when the ovary has

the thickness of a peppercorn. At a little later period, however, an ovule may be discovered; the easiest method of effecting which is, to separate the central substance into two parts, which is best done by gently drawing it to and fro. The ovule forms a club-shaped excrescence, the cellular tissue of which is arranged in concentric layers; each cell contains two phakocysts. On subsequently bringing the ovule, when it has assumed the shape of a small, rather compressed substance, in contact with a drop of water, the water will penetrate it and drive out the phakocyst with some force. The application of a drop of tincture of iodine colours the interior yellow, but leaves the granules uncoloured, which only subsequently become coloured when iodine is applied. Two thin club-shaped bodies are found next to the ovules at this epoch, and some weeks earlier, three fibrous bodies, rather thickened at the end. The author considers these bodies as abortive ovules. The ovule, which is thin at the lower end, might be compared with an embryo-sac, if the position of the surrounding vascular system, and the comparison with the other parts of the fruit, did not contradict it. The young embryo exhibits itself, as a small mass of cells, at the point of the ovule, and nearly in contact with what one might call the epidermis. The author never observed a trace of a pollen-sac in the interior of the ovary, nor did he ever discover the slightest indication of a special integument for the ovule; so that the latter exhibits nothing more than a nucleus, as has been observed in the Santalaceæ, and even in the Olacineæ. This nucleus is attached by its base to the bottom of the ovary, and has its point exactly in the opposite direction, so that the ovule must be regarded as orthotropus. The author never saw a cavity in the ovule of the miseltoe when the embryo was forming, neither did he ever find an embryo-sac. The embryo exhibits itself, first, as already mentioned, at the upper end of the ovule or nucleus; and the embryo cell, or the young embryo itself, is subsequently seen to be attached to a series of cylindrical cells in the cavity of the ovule, which cells constitute a kind of umbilical cord, but without a vascular system."

These observations tend to throw doubt upon the necessity

or universal existence of pollen tubes.* Such processes, observes M. Decaisne, exist, indeed, "in some plants; but in others, where papillæ are situated upon the ovule, as in Arads, they have never been observed, and the papillæ seem to be substituted for them; in other plants again, little bands descend from the base of the style, and are deposited in the seed near the micropyle; for instance, in Composites and some others."

Dr. Dickie, of Aberdeen, has carried this remark further, and has shown, that in many plants the tubes found, at the time of impregnation, in the foramen of the ovule, really originated there, and were not derived from the pollen. His very curious observations will be found at length in the 17th vol. of the *Annals of Natural History,* to which the reader is referred. He has ascertained their existence in plants belonging to Cucurbits, Chenopods, Buckwheats, and Sandalworts; to which may be added Rushes, several Figworts, (Scrophulariaceæ) Parnassia, and probably Orchids.

By some it has been thought that the molecular motile matter found in the interior of pollen grains represented the germs of future embryos, and that the introduction of one such molecule into an ovule was necessary in order to insure the production of an embryo. But it has been shown that the molecules are starch: upon this matter Schleiden has the following remarks:—

"It appears to me, that the very minute chemical and microscopical researches of Fritsche on the pollen (Petersburg, 1837) have made an end of the so called pollen animalcules; for it would be contrary to the laws of animal nature, that the lively motions of these apparent infusoria should continue undisturbed after the addition of alcoholic solution of iodine (a poison that immediately kills all infusoria and animal spermatozoa), as Fritsche states to be the case, and which in many instances I have observed.

"In the Œnotheræ, however, to which Meyen has particularly referred, I have not been able to see anything of

* Gasparrini asserts that the pollen of the Orange tree has no power of emitting pollen tubes.

pollen animalcules (saamenthierchens); and in these cases the contents of the pollen, *quoad solida*, also for the greatest part consist of starch. I have, at least, in Œn. Simsiana, grandiflora, and crassipes, throughout, found nothing else in the pollen besides a solution of gum and those easily recognisable small crescent-formed bodies, which Bronguiart has described as pollen animalcules. They are, however, decidedly starch, and continue starch even when the pollen tube is already deep in the nucleus of the ovule. In order, however, in this case, to detect the starch, we must employ the aqueous solution of iodine, for the alcoholic solution in the first place would coagulate the gum, and in the second it colours the starch so deeply that, on account of the smallness of the grains, one can no longer judge of their colour, and as they are entirely surrounded with the gum, they may easily be supposed to be dark brown. The curvilinear motions of these so called pollen animalcules, which are said to have been observed by a good many, are very easily explained, since at least many of them, being crescent-shaped, when in motion, appear bent to the left, the right, or appear straight, according to their position to the eye."

With respect to the sexuality of plants, that at least would appear, from the facts above recited, to be established beyond controversy; but lately there has arisen in Germany a school of Botanists, at the head of which are Schleiden and Endlicher, who either deny it, or assert that the nature of the phenomenon connected with it has been misunderstood.

Schleiden states that, "if the pollen tubes be followed into the ovule, the most delicate process perhaps that occurs in botanical investigations, it will be found that usually only one, rarely a greater number, penetrates the intercellular passages of the nucleus and reaches the embryo-sac, which being forced forwards, is pressed, indented, and becomes the cylindrical bag which constitutes the embryo in the first stage of its development, and which consequently consists solely of a cell of parenchyma supported upon the summit of the axis. This bag is therefore formed of a double membrane (except the open radicular end), viz. the indented embryo-sac

and the membrane of the pollen tube itself. In Taxus, and especially in Orchis, he has been able to withdraw out of the embryo-sac that portion of the tube which represents the first stage of the embryo, and that indeed at a tolerably advanced period.

"The tracing of the pollen tube into the interior of the embryo-sac is not so easy in all plants; because the cells of the nucleus which are arranged around the summit of the embryo-sac are very firm and opaque, so that it and the pollen tube cannot be exhibited quite free. In these cases, however, three circumstances speak for the identity of the embryo with the pollen tube. 1. The constantly equal diameter of the latter, exterior to the embryo-sac, and of the former, just within it. 2. The invariable chemical similarity of their contents, shown by the reaction produced by the application of water, oil of sweet almonds, iodine, sulphuric acid, and alkalies. The general contents of the grain of pollen is starch; and this either proceeds unchanged downwards through the pollen tube, or else passes along, after being changed by a chemico-vital process into a transparent and colourless fluid, which becomes gradually more and more opaque, and is coagulable by the application of alcohol: out of this, by an organising process, the cells are produced which fill the end of the pollen tube, extending, in Orchis Morio, far beyond the ovule, and thus forming the parenchyma of the embryo. 3. The identity of the embryo and the pollen tube is farther supported by the fact, that, in such plants as bear several embryoes, there is always precisely the same number of pollen tubes present as we find embryoes developed.

"The most important result of these facts is, that the sexual classification hitherto adopted in botany is directly false: for, if the ovulum be understood in physiology to represent that material foundation from which the new being becomes immediately developed, and if we term that portion of the organism in which this material commencement is deposited before it becomes developed the female organ, whilst that part which calls into action or promotes the development of the germ by means of its potential effects is termed the male organ, it is evident that the anther of the

plant is nothing but a female ovarium, and each grain of pollen the germ of a new individual. On the other hand, the embryo-sac only works potentially, determining the organisation and development of the material foundation; and for this reason, therefore, ought to be termed a male principle, were we not to consider, perhaps more correctly (without embarrassing ourselves with lame analogies taken from the animal kingdom), that the embryo-sac merely conveys new organisable fluids by means of transudation, and thus only serves the office of nourishment.

"In the next place, the process of development of the embryo, as already described, easily establishes the analogy of Phanerogamous plants and those Cryptogamic plants in which the spores are evident conversions of the cellular tissue of the foliaceous organs or leafy expansions; for the same part furnishes the groundwork of a new plant in both groups, and the only difference existing between the two is this; in Phanerogamæ a previous formative process in the interior of the plant precedes a period of latent vegetation, whilst in Cryptogamæ the spore (the grain of pollen) developes itself as a plant without previous preparation. Difficulties nevertheless occur here in the consideration of Mosses and Hepaticæ, and more particularly in the enigmatical Marsileaceæ." These statements have now been copiously illustrated by excellent figures in Schleiden's memoir *Ueber Bildung des Eichens, und Entstehung des Embryos bei den Phanerogamen.*

The opinion of Endlicher is to a certain extent that of Schleiden; that is to say, he considers what we call pollen analogous to the spores of Cryptogamic plants, and consequently the anther a female organ, whose contents perform an act similar to that of germination, when they fall upon the stigma; he does not, however, with Schleiden, assign a male influence to the sac of the amnios, but he attributes that property to the stigmatic papillæ, whose moisture lubricates the grains of pollen when they fall upon them.* I

* See *Grundzüge einer neuen Theorie der Pflanzenzeigung.* Professor Wydler of Berne, also, insists upon the pollen being the female apparatus, and he denies that plants have two sexes. (*Recherches sur l' Ovule, &c., des Scrofulaires.*) These

know of no one else who maintains this last opinion; but it deserves to be noted that Morren observed a circulating movement (he calls it cyclosis) in the fluid filling the papillæ of Cereus grandiflorus at the period of impregnation.

Notwithstanding the great mass of evidence which botanists possess in favour of the sexuality of plants, there are certain facts which appear to be irreconcileable with that property; and which wait for further examination.

Mr. John Smith has described in the *Linnæan Transactions*, vol. xviii. p. 510, a Spurgewort, named Cœlebogyne ilicifolia, which, although absolutely female, not possessing a trace of pollen, nevertheless produces perfect seeds. He inclines to the belief that a viscid fluid issuing from glands below the ovary, may produce an effect by exciting the action of the pistil, a supposition which receives some support from the young stigma being often smeared with this fluid. The statement that no male apparatus is discoverable on this plant is confirmed by Francis Bauer and others. We ourselves have often examined the plant without perceiving a trace of stamens or pollen.

Dr. Fresenius has observed that in Datisca cannabina, when female plants remain isolated, they are able nevertheless to produce ripe fruit in abundance; and he concludes that this and other purely female forms are, in the absence of male organs, endowed with the capability of developing, by a purely vegetative process, the highest vital product, the terminal bud (or seed.) In the summer of 1837, a female specimen of the above plant, in the Frankfort Botanical Garden, threw up a stem which now bears male flowers also. (*Linnæa*, 1839.)

Spallanzani, Girou de Buzareingues, and others affirm that

speculations have all arisen out of the undoubted fact, that the development of spores and pollen grains takes place in the same manner, and that there is considerable resemblance in their final structure. This was, I think, first noticed by Mohl (*Ueber die Entwicklung der Sporen, &c.*), in 1833; Mirbel, in 1835, stated that there was a marvellous resemblance between these parts (*Ann. Sc.*, n. s., iv. 9.); Morren declares that the spore is organised like a grain of pollen (*Anat. des Jungermann.* p. 10.); and, finally, Wydler admits a great analogy between the formation of pollen and the spores of many foliaceous cryptogamic plants. (See page 110 of the present volume.)

the female hemp produces ripe seeds in the absence of males: but others assert that if proper precautions are taken to secure the removal of *all* the males the female hemp is barren; Achille Richard, Desfontaines, Marti and Serafino Volta, have obtained the latter result from careful experiments.

On the other hand, Professor Gasparrini declares it to be a well ascertained fact "that the embryo may be formed in the absence of fecundation." This opinion rests upon the following statement:—

"The cultivated Fig tree bears two sorts of fruit (*receptacles, amphanths*); in the spring early figs or *fiorones* (*fioroni*), and in the summer late figs which ripen in the autumn. In the *fiorones* male flowers are very rarely found, and the few which may be present cannot serve for fecundation, for they do not make their appearance until long after the female flowers, nor until the stigmata of the latter are dried and destroyed. Whether it be owing to this or some other cause, I have never yet been able to find seeds with embryos in the *fiorones*.

"The summer fruits, on the contrary, have no male flowers, and yet a large proportion, I may say nearly all of their ovaries become perfect, that is, furnished with embryos.

"It was generally supposed that the cultivated fig was the female, and the wild fig or caprifig was the male of one and the same species; that the latter fecundated the former; and that its fruits, especially those of the spring and autumn, contained at the same time male and female flowers. I have already exposed the error of this opinion (*Nova genera super nonnullis Fici speciebus*, 1844), and have shown that the cultivated and wild Fig trees are so different from one another, that they ought to be looked upon as types of distinct genera. I wished, however, to ascertain whether in spite of their great dissimilarity, one could fertilise the other.

"I have already stated, that the early cultivated figs or *fiorones* never contain seeds with embryos; that if any male flowers do occur in these figs, they cannot fertilise the females because they do not make their appearance till the stigmata

are dried; that the anthers of these male flowers do not open; and, lastly, that the autumn figs only contain female flowers. In very many places an isolated Fig tree is found, which, nevertheless, produces perfect, *i. e.* embryonated seeds. But this observation is not free from uncertainty; for we can suppose an insect of the wild Fig tree to bring pollen, even from a great distance, to the females of the cultivated tree, or that among these there may be accidentally a few male flowers. The first doubt I removed by closing up the eye of the cultivated fig with some gum and clay, when the fruit was very small and before the insect begins to leave the fruits of the wild tree. In spite of this precaution, when the closed figs were ripe, a great many fecundated seeds were found in them. As to the other doubt which can be raised against my view, I repeat that I have never been able to find any more male flowers in the figs which I closed than in the other autumn figs. I moreover searched with extreme care for anything like pollen which might replace it in its fecundating functions, and which might, perhaps, have been hidden in the fruit between the scales of the eye, the peduncles of the flowers, or in any other sheltered place; but my searches were in vain. It is for these reasons that I am led to suppose that in the cultivated fig the embryo of the seed grows and is developed without previous fecundation." (*Annales des Sciences*, sér. 3. tom. 5. p. 306.)

One of the most curious consequences of the presence of sexes in plants is the property the latter consequently possess of producing mules. It is well known, that, in the animal kingdom, if the male and female of two distinct species of the same genus breed together, the result is an offspring intermediate in character between its parents, but uniformly incapable of procreation, unless with one of its parents; while the progeny of varieties of the same species, however dissimilar in habit, feature, or general characters, is in all cases as fertile as the parents themselves. A similar law exists in the vegetable kingdom.

Two distinct species of the same genus will often together produce an offspring intermediate in character between

themselves, and capable of performing all its vital functions as perfectly as either parent, with the exception of its being unequal to perpetuating itself permanently by seed; should it not be absolutely sterile, it will become so after a few generations. It may, however, be rendered fertile by the application of the pollen of either of its parents; in which case its offspring assumes the character of the parent by which the pollen was supplied. This power of hybridising appears to be far more common in plants than in animals; for, while only a few animal mules are known, there is scarcely a genus of domesticated plants in which this effect cannot be produced by placing the pollen of one species upon the stigma of another. It is, however, in general only between nearly allied species that this intercourse can take place: those which are widely different in structure and constitution not being capable of any artificial union. Thus the different species of Strawberry, of certain tribes of Pelargonium, and of Cucurbits, intermix with abundant facility, there being a great accordance between them in general structure and constitution; but no one has ever succeeded in compelling the Pear to fertilise the Apple or the Gooseberry the Currant. And as species that are very dissimilar appear to have some natural impediment which prevents their reciprocal fertilisation, so does this obstacle, of whatever nature it may be, in general present an insuperable bar to the intercourse of different genera. The stories that are current as to the intermixture of Oranges and Pomegranates, of Roses and Black Currants, and the like, may be set down to pure invention.

It is, nevertheless, said, that *bigeners*, that is to say, mules between different genera, have in some few cases been artificially obtained. Kölreuter obtained such between Malvaceous plants; Gærtner, between Datura and Henbane and Tobacco; Wiegman, between a Garden Bean and a Lentil; and there are other cases. But all such productions were as short-lived and sickly as they were monstrous.

As this power of creating mule plants fertile for two or three generations incontestably exists, it is not to be wondered at, that in wild nature hybrid varieties should be far from

uncommon. Among the most remarkable cases are, the Cistus Ledon, constantly produced between C. monspessulanus and laurifolius; and Cistus longifolius, between C. monspessulanus and populifolius; in the wood of Fontfroide, near Narbonne, mentioned by Bentham. The same acute botanist ascertained that Saxifraga luteopurpurea of Lapeyrouse, and S. Ambigua of De Candolle, are only wild accidental hybrids between S. aretioides and calyciflora: they are only found where the two parents grow together; but there they form a suite of intermediate states between the two. Gentians, having a similar origin, have also been remarked upon the mountains of Europe; and altogether about forty cases of wild reputed species of the genera Ranunculus, Anemone, Hypericum, Scleranthus, Drosera, Potentilla, Geum, Medicago, Galium, Centaurea, Stachys, Rhinanthus, Digitalis, Verbascum, Gentiana, Mentha, Quercus, Salix, and Narcissus, have been collected by Schiede, Lasch, and De Candolle; to which far too many may be added from the works of species-making botanists. It is impossible not to believe that a great proportion of the reputed species of Rosa, Rubus, and other intricate genera, have had a hybrid origin.

Mr. Thwaites has made some very interesting remarks upon the light which these mules throw upon the phenomena of vegetable impregnation.

"The most eminent physiologists," he observes, "seem to be arriving at the opinion that the fertilisation of the ovule, as it is termed, consists in the union of a part of the contents of a pollen-grain with certain matter contained in the ovule, and that the embryo originates from this mixed matter. The correctness of this opinion is rendered still more probable by the consideration of what takes place under the circumstances of hybridisation of species. The phenomena which present themselves in these cases are of the highest physiological interest, and it seems impossible after a careful consideration of them to doubt that the hybrid plant owes its existence to—consists in its earliest condition of—an endochrome made up of a portion of the endochrome of each of the parent plants; for the development of the hybrid embryo into the mature

plant indicates a quality of the contents of this embryonic cell of a character combining that of the endochrome of each of the two parents. A few facts will best illustrate the meaning of the foregoing observations. The ovules of Fuchsia coccinea fertilised with the pollen of Fuchsia fulgens produce plants of every intermediate form between these two species—some of the seedling plants closely resembling one, and others the other species, but the majority partaking equally of the characters of the two parents: scarcely, however, will any two be found so much alike as to be undistinguishable from each other. With respect to each of the hybrid seedlings, separately considered, there is a uniformity throughout in the mixed character of its various parts; so that it is easy from the examination of the foliage to arrive at a tolerably correct idea of what will be the character of the blossom. Some persons perhaps will be disposed to believe that an endochrome may be modified in its character, that the peculiarities of the hybrid plant may be produced by the situation in which it is at first developed; but if this were the fact, it is clear that the hybrid seedlings ought all to resemble each other as much as do individuals of one species, which is far from the truth, as has been just now stated. Moreover, a fact came under the observation of the writer which completely sets aside the idea of such an explanation of the phenomena, for in one example of the hybrid Fuchsia seedlings the singular circumstance occurred of one seed producing two plants extremely different in appearance and character; one of them partaking rather of the character of Fuchsia fulgens and the other of Fuchsia coccinea. It cannot be doubted that these very dissimilar structures were the produce of one seed, since they were closely coherent, below the two pairs of cotyledon leaves, into a single cylindrical stem, so that they had subsequently the appearance of being branches of one trunk. The plant was unfortunately, before flowering, killed by an unexpected severe frost, but not before its peculiarity had been observed by many persons besides the writer. In the case just cited the idea of a modification of structure caused by mere circumstance of situation in the early stage of growth is quite untenable; for were such the

case, it is clear there could not have been the great dissimilarity which presented itself in these twin-plants—the produce of a single seed." (*Annals of Natural History*, i. n. s. 163.)

This view of the essential phenomena of fertilisation receives much apparent support from some singular cases of quasi-hybrid plants, which do not appear to have been produced from seed, but are believed to have sprung from the accidental mixture or grafting of common cellular tissue. A Citrus, which produces fruit whose rind is that of the orange in part and of the lemon in part, is supposed to have had such an origin: but the most singular example is to be found in a plant called in the gardens Cytisus Adami, or the purple hybrid Laburnum, whose flowers and leaves are sometimes those of Cytisus Laburnum, sometimes of Cytisus purpureus, and sometimes intermediate between the two. Dr. Herbert, in his learned paper on hybrids, in the *Journal of the Horticultural Society*, speaks of it thus:—

"In the garden of the late Mr. Loudon, at Bayswater, upon a large shrub of the same hybrid, one of the limbs resolved itself into its elements, diverging into two branches, one of which had the small weeping habit, leaves, and flowers of C. purpureus, the other nearly the leaves and racemes of yellow flowers belonging to the common laburnum; and those two branches ripened good seed, whilst the rest of the shrub producing the hybrid blossom was absolutely sterile. The seeds borne by the smaller branch were less abundant and had been lost; those on the yellow branch were plentiful, and I raised many plants from the seeds, which were kindly given to me by Mr. Loudon. They returned nearly to the form of the common laburnum, excepting that two of the seedlings showed a little purple tinge on the green stalks, which might, perhaps, have extended to the flowers, but they were lost by neglect. In the same season the diminutive branch on my brother's tree bore seed, and from it I raised plants, differing very little from the usual C. purpureus. The history of the plant is, that it was not raised from seed, but made its appearance in the following remarkable way:—A number of stocks of laburnum had been budded with C. purpureus in a French nursery-garden, and the bud on one

of them died; but the wood and bark inserted lived, as frequently occurs in such cases. After some time new eyes formed themselves, one of which produced this hybrid, C. Adami. I suggested, in a communication to Mr. Loudon, that it must have broken from the exact juncture, and proceeded from a cell of cellular tissue formed by the union of two cells, which had been cut through, and had grown into one, and which, therefore, belonged to the two different plants, half a cell of the tissue of C. purpureus having been spliced to half a cell of C. laburnum. The necessary consequence would be that a bud formed from that compound cell would derive qualities from both species, but qualities less fixed and innate than those which are derived from generative union. This has been looked upon as a speculation, but I consider it nearly amounting to a certainty, because I think that the consequence is necessary, and that the phenomena cannot be accounted for in any other manner; and nothing of the sort has occurred to any known mule production, vegetable or animal. Since that time my brother's shrub has put out many of the large-leaved yellow branches and of the small branches, and they are fertile. It occurred to me that it would be a confirmation of my view, if the reverted branches of each kind should keep to opposite sides of the stem; and on examination that proved to be decidedly the case. Whether that circumstance occurs elsewhere or not, I do not know; but it looks as if one side of the wood adopted the character of one half of the original cell, and the opposite side the other character. I think that clever gardeners might thus obtain crosses between plants which will not intermix seminally."

In a practical point of view, I am inclined to believe that the power of obtaining mule varieties by art is one of the most important means that man possesses of modifying the works of nature, and of rendering them better adapted to his purposes. In our gardens some of the most beautiful flowers have such an origin; as, for instance, the roses obtained between R. indica and moschata, the different mule Potentillæ and Cacti, the splendid Azaleas raised between A. pontica and A. nudiflora coccinea, and the magnificent

American-Indian Rhododendrons. By crossing varieties of the same species, the races of fruits and of culinary vegetables have been brought to a state as nearly approaching perfection as we can suppose possible. And if similar improvements have not taken place in a more important department, namely, in corn, or in the trees that afford us timber, experience fully warrants the belief that, if proper means were adopted, improved varieties of as much consequence might be introduced into our fields and forests, as have already been created for our gardens.

The best paper we possess upon the practical value of the facts elicited by hybridising, is to be found in the *Journal of the Horticultural Society*, from the pen of the late Dean of Manchester, a gentleman whose whole life was spent in pursuits which enabled him to watch the phenomena in question, and whose highly cultivated intellect taught him how to reason upon them philosophically. In the following striking passages we have the general result of Dr. Herbert's views on this subject:—

"I will therefore state, briefly and humbly, what is the general bias of my surmises as to the diversification of vegetables, to which that of animals must be in a certain degree analogous. We know that four races of men have branched out from one stock,—the white, the black or African, the brown or Asiatic, and the red, with various subdivisions of aspect amongst them, and we know nothing of the mode or time in which those diversities arose. Revelation and history are equally silent on those facts. They must have occurred very early. Jupiter is said to have visited the Ethiopians; and M. Faber has proved that the things recorded of Jupiter relate to the period which immediately followed the deluge. We may therefore assume that such changes began in the lifetime of the sons of Noah, or were immediately consequent on the dispersion of mankind. We are equally in the dark as to the races of dogs. Old writers allude to different kinds of dogs, and we do not know when or how any one of those we possess originated; and the same may be said with respect to the origin of languages. From these facts I draw this inference, which seems to me incontrovertible, that a course

of change was in operation in the early ages after the deluge, which had ceased, or at least was greatly diminished, before the era at which our knowledge of events began to be more precise, and handed down by writing. I shall be told that these different races of men breed freely together, and that these dogs intermix, and produce mongrels also, and that we see thereby that they are only varieties of one kind. Granted; I entertain no doubt of their having respectively descended from one pair of created individuals; but how do you prove to me that the cat, lynx, tiger, panther, lion, &c., did not descend from one created pair? I am rather inclined to think that they did (but this only a surmise), and even the horse and the ass from one created pair; and I am quite unable to believe that the several sylviæ of the wren family, some of which can with difficulty be distinguished except by the proportions of their quills, and which have nevertheless very diverse habits, notes, and nests, were created separately and specially; and, when I look to the vegetable races, I am still more unwilling to assent to the assertion, that every plant, which this or that botanist has called a distinct species, or even a distinct genus, had a special creation in the period before the sun and moon shone upon this world, when God created vegetables. Upon what authority is such an assertion made? Upon none but the dictum of those who are pleased to inculcate it. Upon what ground is it made? Upon none that will bear investigation,—upon a rash assumption that everything cross-bred is sterile, and that if the offspring is sterile the parents are thereby proved to have been descended severally from the Creator. In the first place, the fact is even false as to animals. Buffon records an instance of the fertility of a mule. I have seen that which I am satisfied was a hybrid between a bitch and a fox, which was the father of many puppies. But if the fact were positively true, how is it to be proved that the constitution and frame may not have undergone such changes in the diversification as to prevent intermixture? If I can show that in one genus of plants cross-breeding is not only easy, but more easily obtained than fertility by the plant's own pollen, and that in others, so closely allied to it, as to make it a question whether they are

not sections of one genus, cross-breeding cannot be effected generally, and in no case easily; that in some genera of plants many or all the cross-bred varieties are fertile, and in others nearly allied thereto all, or almost all, are sterile; the assertion that the races of canis or dog must have had one origin because their crossed produce is fertile, and the races of felis, from the cat to the tiger, must have had separate origin because their crossed produce is sterile (supposing the fact to be true, which is not ascertained), must fall to the ground. The only thing certain is, that we are ignorant of the origin of races; that God has revealed nothing to us on the subject; and that we may amuse ourselves with speculating thereon, but we cannot obtain negative proof, that is, proof that two creatures or vegetables of the same family did not descend from one source. But we can prove the affirmative; and that is the use of hybridising experiments, which I have invariably suggested; for if I can produce a fertile offspring between two plants that botanists have reckoned fundamentally distinct, I consider that I have shown them to be one kind; and indeed I am inclined to think that, if a well-formed and healthy offspring proceeds at all from their union, it would be rash to hold them of distinct origin. We see every day the wide range of seminal diversities in our gardens. We have known the dahlias from a poor single dull-coloured flower break into superior forms and brilliant colours; we have seen a carnation, by the reduplication of its calyx, acquire almost the appearance of an ear of wheat, and look like a glumaceous plant; we have seen hollyhocks in their generations branch into a variety of colours, which are reproduced by the several descendants with tolerable certainty. We cannot, therefore, say that the order to multiply after their kind meant that the produce should be precisely similar to the original type; and, if the type was allowed to reproduce itself with variation, who can pretend to say how much variation the Almighty allowed? Who can say that His glorious scheme for peopling and clothing the earth was not the creation of a certain number of original animals and vegetables, predestined by Him in their reproduction to exhibit certain variations, which should hereafter become

fixed characters, as well as those variations which even now frequently arise and are nearly fixed characters, but not absolutely so, and those which are more variable and very subject to relapse in reproduction ?"

The cause of the frequent sterility of mule plants is at present unknown. Sometimes, indeed, a deficiency of pollen may be assigned; but in many cases there is no perceptible difference in the healthiness of structure of the fertilising organs of a mule plant and of its parents. Professor Henslow, of Cambridge, in an excellent paper upon a hybrid Digitalis, investigated anatomically the condition of the stamens and pistil, both of his hybrid and its two parents, with great care and skill. The result of his inquiry was, that no appreciable difference could be detected.

Dr. Herbert's views were the following:—"I suspect that it is by the nice adaptation of the juices of each individual type to yield the exact proportion of what is wanted for the pollen of its kind, that the Almighty has limited the races of created things; and that, wherever that adaptation is perfect, a perfect offspring is produced. Where it is not perfect, an inadequate or a weak fertilisation takes place. It is further to be observed that there is frequently an imperfect hybrid fertilisation, which can give life, but not sustain it well. There are several crosses which I have repeatedly obtained, but could not raise the plants to live for any length of time. I obtained much good seed several years ago from Hibiscus palustris by speciosus; I sowed a little each year till it was all gone; the plants always sprouted, but I saved only one to the third leaf, and it perished then. I have never raised beyond the third or fourth leaf a cross between Rhododendron ponticum and an orange Azalea, though I have saved two or three through the first winter. My soil, however, is very uncongenial to them, and under more favourable circumstances they would have been saved. From Rhodora canadensis by Azalea pontica (sections of genus Rhododendron), I saved ultimately only one out of more than a hundred seedlings, and that became a vigorous plant. Such crosses sometimes are a hundred times more delicate in their

first stage than natural seedlings. Mr. Bidwill, in attempting crosses at Sydney, has also (as he informs me) raised some with difficulty, which have invariably perished. In these cases I apprehend that, although the affinity of the juices is sufficient to enable the pollen to fertilise the ovule, the stimulus is insufficient, the operation languid, and the fertilisation weak and inadequate to give a healthy constitution. It has been generally observed that hybrid fertilisation is slower than natural fertilisation, and that often a much smaller number of ovules are vivified. The same cause probably operates in that respect: the affinity not being perfect, the necessary ingredients are attracted by the pollen less readily and insufficiently, and by many of the grains not at all."

CHAPTER X.

OF THE FRUIT.

THE fruit is mechanically destined as a mere protection to the seed; it constitutes the principal part of the food, especially in winter, of birds and small animals; it is often more ornamental than the flowers themselves, and it contributes most materially to the necessities and luxuries of mankind. When ripe, it falls from the plant, and, borne down by its weight, lies on the ground at the foot of the individual that produced it: there its seeds vegetate, when it decays, and a crop of new individuals arises from the base of the old one. But, as plants produced in such a manner would soon choke and destroy each other, nature has provided a multitude of ways for their dispersion. Many are carried to distant spots by the animals which eat them: others, such as the Samara, and the pappus of Composites provided with a sort of wing, fly away upon the wind to seek a distant station; others scatter their seeds abroad by an explosion of the pericarp, caused by a sudden contraction of the tissue; many, falling upon the surface of streams, are carried away by the current; while others are dispersed by methods which it would be tedious to enumerate.

The fruit, during its growth, is supported at the expense of the sap generally: but most especially of that which had been previously accumulated for its maintenance. This is less apparent in perennial or ligneous plants than in annual ones, but is capable of demonstration in both. Knight has well observed, that in annual fruit-bearing plants, such as the Melon, if a fruit is allowed to form at a very early period of the life of the plant, as, for instance, in the axil of the

third leaf, it rarely sets or arrives at maturity, but falls off soon after beginning to swell, from want of an accumulation of food for its support; while, if the same plant is not allowed to bear fruit until it has provided a considerable supply of food, as will be the case after the leaves are fully formed, and have been some little time in action, the fruit which may then set swells rapidly, and speedily arrives at the highest degree of perfection of which it may be susceptible. And in woody trees, also, a similar phenomenon is observable: it is well known to gardeners, that, if a season occurs in which trees in a state of maturity are prevented bearing their usual crops, the succeeding year their fruit is unusually fine and abundant; owing to their having a whole year's extra stock of accumulated sap to feed upon.

The cause of the fruit attracting food from surrounding parts is probably to be sought in the phenomenon called endosmose. The sap that may be at first impelled into the fruit by the action of vegetation, not being able to find an exit, collects within the fruit, and, in consequence of evaporation, becomes gradually more dense than that in the surrounding tissue: it will then begin to attract to itself all the more aqueous fluid that is in communication with it; and the impulse, once given in this way to the concentration of the sap in particular points, will continue until the growth of the fruit is completed, and its tissue so much gorged as to be incapable of receiving any more food, when it usually falls off.

No one has studied the effects of fruit upon the atmosphere, and the nature of the chemical changes it undergoes, with more success than Théodore de Saussure and Bérard, an account of whose discoveries I partly translate and partly condense from De Candolle. According to the first of these original observers, "Fruits, while green, whether leafy or fleshy, act much as leaves either in the sun or in shade, and differ from those organs principally in the intensity of their action. In the night they destroy the oxygen of their atmosphere, and replace it with carbonic acid, which they partially absorb again. This absorption is generally less in the open air than under a receiver; and, their volume remaining the

same, they consume more oxygen in darkness when distant from ripeness, than when they are approaching that state. If exposed to the sun, they disengage altogether or in part the oxygen which they inhaled during the night, and preserve no trace of this acid in their own atmosphere. If many fruits are detached from the plant, they thus add oxygen to air which contains no carbonic acid. When their vegetation is very feeble, or extremely languid, they vitiate the air under all circumstances, but less in the sun than in the shade. Green fruits detached from a plant, and exposed successively to the action of the sun and of darkness, change it but little or not at all either in purity or in volume. The trifling variations that may be remarked in this respect depend either upon the greater or less faculty which they have of elaborating carbonic acid, or on their composition, which is modified according to the degree of their ripeness. Thus Grapes, in a state of verjuice, appear to assimilate in small quantity the oxygen of the carbonic acid which they form in the air where they vegetate both day and night; while, on the contrary, Grapes nearly ripe give back almost entirely, during the day, to their own atmosphere, the oxygen of the carbonic acid they have formed in darkness. If there is no deception in this circumstance, which, although feeble, appears to have been constant, it marks the passage from the acid to the sweet state, by indicating that the acidity of verjuice depends upon the fixing of the oxygen of the air, and that this acidity disappears when the fruit no longer seeks for carbon in the air or in carbonic acid. Green fruits decompose, either entirely or in part, not only the carbonic acid they have produced during the night, but, in addition, such quantity as may be artificially added to their atmosphere. When this last experiment is tried with fruits which are not watery, and which, like Apples and Grapes, elaborate carbonic acid slowly, one sees that they absorb in the sun a much larger proportion of gas than the same volume of water in a similar mixture; afterwards they disengage the oxygen of the carbonic acid absorbed, and thus appear to elaborate it in their interior.

"They appropriate to themselves during their vegetation

both oxygen and water, compelling the latter to lose its liquid state.

"These results are often not observable in volumes of air less than from thirty to forty times that of the volume of the fruit, and by diminishing the heating power of the sun. If such precautions are neglected, many fruits will vitiate the air, even in the sun, by forming carbonic acid with the ambient oxygen; but, even in the latter case, the simple comparison of their effect in light, with that produced under the influence of night and darkness, demonstrates that they decompose carbonic acid."

In ripening, fruits undergo some remarkable alterations, which have been thus explained by De Candolle, in his abridgment of Bérard's observations:—

"If we examine the modifications which the flesh of fruits undergoes in ripening, we shall at first remark that their fibrous or cellular tissue (which varies very much in quantity in different species) is merely lignine: in most cases, especially in very fleshy fruits, lighter, less tough, and more easily soluble in alkaline solutions, than common lignine; but presenting characters of an opposite kind in other parts of the same fruit, such as their stones.

"The liquid which fills the flesh of succulent pericarps consists of sap placed in the intercellular passages, and of the matter contained in the cells. This liquid of the flesh, or of the fleshy endocarp, besides a great quantity of water, contains sugar, gum, malic acid, malate of lime, colouring matter, a peculiar vegeto-animal substance, and an aromatic secretion proper to each fruit: there is, moreover, in certain cases, the tartrates both of potash and of lime, as in Grapes; and citric acid in the Lemon, and even in small quantity in the Gooseberry." Bérard could find no trace of starch in watery fruits, such as Cherries, Plums, Peaches, Currants, Grapes, nor even in Pears and Apples, although it has been said to exist in them.

"A comparison of the analysis of certain fruits, before they are ripe and at that period, gives some curious results. In the first place there is a disappearance of water in a liquid state, viz., per cent.:—

	"Water before ripeness.	Water at ripeness.
"Apricots	89·39	74·87
Currants	86·41	81·10
Duke Cherries	88·28	74·85
Green Gages	74·87	71·10
Melting Peaches	90·31	80·24
Jargonelle Pears	86·28	83·88

"This diminution appears to depend in part upon the fruit absorbing less water as it approaches maturity, and in part upon the combination with its tissue of a portion of the water it has received. Sugar, on the contrary, appears to be continually on the increase, as indeed the taste would tell us; thus we find, per cent.—

	"Green.	Ripe.
"Apricots (a trace when young, afterwards)	6·64	16,48
Red Currants	0·52	6·24
Duke Cherries	1·12	18·12
Green Gage Plums	17·71	24·81
Melting Peaches	0·63	11·61
Jargonelle Pears	6·45	11·52

"This sugar is sometimes in a state more or less concrete, as in the Grape, the Fig, and the Peach; sometimes in a liquid state. It seems to be formed at the expense of other matters, the proportion of which diminishes. Thus the quantity of lignine per cent. is found—

	"Green.	Ripe.
"Apricots	3·61	1·86
Currants (including the seeds)	8·45	8·01
Duke Cherries	2·44	1·12
Green Gage Plums	1·26	1·11
Melting Peaches	3·01	1·21
Jargonelle Pears	3·8	2·19

"It is possible, indeed, that the lignine formed in the green fruit does not in reality diminish, but that the dilatation of the cellular tissue, and consequently the augmentation of

the aqueous products, render it proportionably less, without its being absolutely so. But the gummy, mucilaginous, or gelatinous matters, appear very susceptible of changing into sugar; thus, Couverchel found that, if we treat Apple jelly with a vegetable acid dissolved in water, we obtain a sugar analogous to that of Grapes; that the gum of Peas, placed with oxalic acid, in a temperature of 125° Réaum., changed to sugar; that gum extracted from starch, if mixed with the juice of green Grapes, rendered the latter saccharine; and finally that tartaric acid will produce the same effect by aid of heat: this is the reason why most fruits become sweet when cooked.

"Other matters offer remarkable disparities between one fruit and another: thus malic acid keeps diminishing in Apricots and Pears, augmenting in Currants, Cherries, Plums, and Peaches. Gum keeps diminishing in Currants, Cherries, Plums, and Pears, and augmenting in Apricots and Peaches. Animal matter keeps diminishing in Apricots and Plums, and increasing in Currants, Peaches, Cherries, and Pears. Lime, which never exists except in small quantity, seems generally to diminish, probably because evaporation becomes less with maturity.

"After the period which is generally called that of ripeness, most fleshy fruits undergo a new kind of alteration; their flesh either rots or *blets*.* These two states of decomposition cannot, according to Bérard, take place, except by the action of the oxygen of the air, although he admits that a very small quantity is sufficient to cause it. He succeeded in preserving for several months, with little alteration, the fleshy fruits which were the subjects of the foregoing experiments, by placing them in hydrogen or nitrogen gases. All fruits at this extreme period of their duration, whether they decay or whether they blet, form carbonic acid with their own carbon and the oxygen of the air, and moreover disengage from their proper substance a certain quantity of carbonic acid.

"Bletting is in particular a special alteration. I have

* May I be forgiven for coining a word to express that peculiar bruised appearance in some fruits, called *blessi* by the French, for which we have no equivalent English expression?

remarked, in another place, that this condition is not well characterised in any other fruits than those of Ebenaceæ and Pomaceæ; that both these natural orders agree in having the calyx adherent to the ovary, and that their fruits are austere before ripening. It would even seem, from the fruits of Diospyros, the Sorb, and the Medlar, that the more austere a fruit is, the more it is capable of bletting regularly.

"It has been found that a Jargonelle Pear, in passing to this state, loses a great deal of water (83·88 reduced to 62·73), pretty much sugar (11·52 reduced to 8·77), and a little lignine (2·19 reduced to 1·85); but acquires rather more malic acid, gum, and animal matter. Lignine, in particular, seems, in this kind of alteration, to undergo a change analogous to that of wood in decay."

The foregoing experiments have led to the discovery, that fruits which do not require to remain on the tree may be preserved for some time, and thus the pleasure they afford us prolonged. A simple process is said to consist in placing, at the bottom of a bottle, a paste formed of lime, sulphate of iron, and water, and afterwards introducing the fruit, it having been pulled a few days before it would have been ripe. Such fruits are to be kept from the bottom of the bottle, and as much as possible from each other; and the bottle is to be closed by a cork and cement. The fruits are thus placed in an atmosphere free from oxygen, and may be preserved for a longer or shorter time, according to their nature: Peaches, Prunes, and Apricots, from twenty days to a month; Pears and Apples for three months. If they are withdrawn after this time, and exposed to the air, they ripen well; but, if the times mentioned are much exceeded, they undergo a particular alteration, and will not ripen at all.

CHAPTER XI.

OF GERMINATION.

The action of the seed is confined to that phenomenon which occurs when the embryo that the seed contains is first called into life, and which is named germination.

If seeds are sown as soon as they are gathered, they generally vegetate, at the latest, in the ensuing spring; but, if they are dried first, if often happens that they will lie a whole year or more in the ground without altering. This character varies extremely in different species. The power of preserving their vitality is also variable: some will retain their germinating powers many years, in any latitude, and under almost any circumstances. Melon seeds have been known to grow when 41 years old, Maize 30 years, Rye 40 years, the Sensitive plant 60 years, Kidneybeans 100 years. Clover will come up from soil newly brought to the surface of the earth, in places in which no clover had been previously known to grow in the memory of man, and I have at this moment three plants of Raspberries before me, which have been raised in the garden of the Horticultural Society from seeds taken from the stomach of a man, whose skeleton was found thirty feet below the surface of the earth, at the bottom of a barrow which was opened near Dorchester. He had been buried with some coins of the Emperor Hadrian, and *it is therefore probable that the seeds were sixteen or seventeen hundred years old.*

The chemical action of seeds has been well explained by De Candolle, to whom, however, the recent observations by Edwards and Colin were unknown.

Water, heat, and atmospheric air (or at least oxygen) are the conditions without which germination cannot take place.

If any one of them is abstracted, the other two are of no effect: it is, however, doubtful whether it ever happens in nature, that the act of germination takes place under conditions so simple as those; it is usually a more complicated phenomenon.

Water is the agent to which we are most in the habit of assigning the power of causing the growth of seeds; to air and heat they are generally exposed more or less, and it is by the addition of water that the two latter are popularly considered to be brought into active operation. According to De Candolle, it is a general property of seeds to absorb, during their period of germination, more than their own weight of water; but no regular proportions have been remarked, and it is probable that the respective power of different seeds depends upon the nature of the matter deposited in their tissue. One effect of water may be supposed to be that of softening the tissue, of enabling all the parts to distend, and of dissolving the soluble parts so as to render them fit to be taken into the circulation, as the young plant becomes capable of absorbing them. Another effect is to yield hydrogen by its decomposition.

Germination cannot take place *in vacuo;* nor in an atmosphere of nitrogen or hydrogen, and still less in carbonic acid; or at least, if in this latter gas some traces of germination manifest themselves, they rapidly disappear: it can only occur in free oxygen. Of this but a small proportion is really necessary; from $\frac{1}{6}$ to $\frac{1}{32}$, according to different observers. But one part of oxygen and three of nitrogen are the proportions which seem to be the most favourable, and this is not very different from the proportions in atmospheric air; viz., one of oxygen and four of nitrogen. A too large dose of oxygen weakens the young plant, by abstracting its carbon too rapidly.

Experiments show that oxygen is not absorbed by the seed, but combines with its carbon, forming carbonic acid, which is thrown off. When a seed ripens, a considerable quantity of carbon is stored up in its tissue, apparently for the purpose of enabling it to "maintain the unalterability" to which its preservation is owing. This superfluous carbon

renders it scarcely soluble in water. To enable the parts to be sufficiently moistened, it is therefore necessary that the seed should be decarbonised by oxygen. This explains why Peas scarcely ripe will germinate much more rapidly than those which are fully matured; the former contain more pure water and less carbon. In fact, the effect of the abstraction, by oxygen, of the fixed carbon, is, to bring back the seed to the state in which it was, before it was provided with the means of remaining unchanged in a torpid state. The sweet taste of germinating barley is, in reality, what the seeds possessed before they were finally hardened. The destruction of oxygen, by the carbon of the seed, produces a sensible heat in germination, just as a similar cause produces a similar effect in flowers, when the fæcula of their disc is converted into sugar (see p. 211). Hence the heat of masses of Barley which are made to germinate in darkness in order to become malt: and it can scarcely be doubted, that the change of the starch of that grain into sugar is chemically owing to the abstraction of a proportion of its carbon, and the addition of some other proportion of oxygen.

It has been asked, Whence comes the oxygen which, combining with the carbon of the seed, forms the carbonic acid expelled in germination? The usual answer is, From the air: and it is necessary that seeds should have access to the atmosphere in order to germinate. But Messrs. Edwards and Colin have shown, by recent experiments, that the oxygen of which germinating seeds make use is obtained by the decomposition of water, and not necessarily from the air. These physiologists placed Beans in water, under such circumstances that they were completely cut off from access to the air. The Beans disengaged bubbles of air from their sides in great abundance for the space of four days, a part of such air collecting in a receiver, but the greater part dissolving in the water. This air consisted chiefly of carbonic acid; there was also a trace of oxygen, and a small quantity of what appeared to be nitrogen. The hydrogen left after the decomposition of the water appeared to be absorbed by the seed, either wholly or in great part. This proof of the decomposition of water by the vital energies of the seed is justly stated,

by the authors now quoted, to be a fact of the first importance. (*Comptes rendus,* vii. 922.)

It also appears that the carbon of seeds is lost, not only by the formation of carbonic acid, but by the production of acetic acid, during germination, a phenomenon which Messrs. Becquerel and Boussingault consider constant. (*Comptes rendus,* vi. 109.)

In the opinion of some persons, oxygen also acts as a stimulant of the vital actions of the embryo. Humboldt remarked that seeds plunged in chlorine, and taken out before the radicle appears externally, germinate more rapidly than ordinary; Cress, for instance, may thus be made to germinate in six hours instead of twenty-four or thirty. He even succeeded, by this process, in bringing about germination in old seeds which appeared destitute of the power. These experiments have not, however, succeeded in all hands: in many cases it is possible that the success that is said to have attended them has been imaginary; and, as the theory upon which the action of chlorine was explained is now abandoned, one cannot avoid entertaining doubts as to the accuracy of the alleged fact.

It is heat in which the stimulus necessary to call the vitality of seeds into action seems really to reside. No seed can germinate at a temperature so low as that of freezing; and each seems to have some one temperature more proper for it than any other, at the first dawn of its life. If, says De Candolle, the temperature is too high, germination proceeds too rapidly, and the result is weak and languishing plants, in which we cannot avoid recognising beings too much excited and badly nourished. If the temperature is too low, the excitement is not sufficient; and it often happens that the seed cannot resist the decay induced by the water it has absorbed, but not assimilated. It is between these limits that a suitable temperature for every species is to be sought.

Edwards and Colin have instituted some experiments to determine what temperature seeds can bear. They found that Wheat, Barley, and Rye could germinate at 7° centig. (44·6° Fahr.); and that grain of the same description did not

apparently suffer, by being exposed for a quarter of an hour to a temperature equal to freezing mercury: such grains were afterwards placed in a proper situation, and germination took place as usual. Considering that the particles of fæcula of which seeds consist are not liable to bursting below a temperature of 75° centig. (167° Fahr.), these observers were led to ascertain how near an approach to this extreme temperature might be made, without destroying vegetable life. Seeds of various cereal and leguminous plants were placed for a quarter of an hour in water of this temperature, and they were all killed; five minutes were afterwards ascertained to suffice for the destruction of three in five. Less elevated temperatures were next experimented on. Wheat, Barley, Kidneybeans, and Flax were killed in 27½ minutes, by water at 62° centig. (143·6° Fahr.); a few grains of Rye and some Beans required a longer exposure to be destroyed. When the temperature was lowered to 52° centig. (125·6° Fahr.), most of the seeds in experiment retained their vitality; but even this was fatal to Barley, Kidneybeans, and Flax.

Fluid water has conducting powers very different from those of vapour or of dry air; it was thereupon important, to determine whether the temperature that seeds can bear is regulated by the nature of the medium in which they are exposed to it. In vapour, 75° centig. (167° Fahr.) was sufficient to destroy such seeds as were exposed; but, at 62° centig. (143·6° Fahr.), they retained their vitality, after having been under experiment for a quarter of an hour. But, in dry air, many seeds bore the temperature of 75° centig. (167° Fahr.), for a quarter of an hour, without inconvenience. Hence it appears that seeds in steam can bear 12° centig. more than in water, and in dry air 13° centig. more than in steam.

In these experiments, the action of temperature was extremely rapid. In lowering the temperature and prolonging its action, it was found that, when Wheat, Rye, and Barley were exposed for three days, in water, to a temperature of 35° centig. (95° Fahr.), four-fifths of the Wheat and Rye, and all the Barley, were killed. Hence it would appear,

that 35° centig. forms the highest limit of temperature which corn can bear under such circumstances. But, in sand or earth, the same grains sustained a prolonged temperature of 40° centig. (104° Fahr.) without inconvenience; at 45° centig. (113° Fahr.) a great part perished; at 50° centig. (122° Fahr.) the whole of them.

These remarkable experiments are calculated to throw great light upon the cause of the impossibility of making certain plants multiply themselves by seeds in hot countries. If Wheat, Barley, &c., cannot endure a prolonged temperature above 40° centig.; and the temperature of the soil is in some countries and soils as high as 60° centig. (140° Fahr.), as Humboldt asserts, or between 48° and 53° centig. (122° Fahr.), even in some parts of France, as Arago states; it is evident that the seeds of corn placed in such situations will perish.

Some seeds will, however, bear a very high temperature with impunity. Those of New Holland Acacias germinate readily after having been boiled for as long as five minutes, perhaps in consequence of the softening of their skin and tissues; and a case is mentioned by Mr. Hemingway, (*Ann. of Nat. History,* vol. viii. p. 317), of the seeds of the Elder (Sambucus) which germinated readily after they had twice been boiled in making wine, had been present during the vinous fermentation, and had been allowed to remain among the dregs of the wine bunged up in the cask for a period of twenty months. In like manner the seeds of the Raspberry have been known to retain their vitality after being boiled in sugar, in the operation of making raspberry-jam.

Exposed to the influence of water, heat, and air, the parts of a seed soften and distend; the embryo swells and bursts its envelopes, extending the neck and the bases of the cotyledons, and finally emitting its radicle, which pierces the earth, deriving its support at first from the cotyledons or albumen, but subsequently absorbing nutriment from the soil, and communicating it upwards to the young plant. The manner in which the embryo clears itself from its integuments differs in various

species: sometimes it dilates equally in all directions, and bursts through its coat, which thus becomes ruptured in every direction; more frequently the radicle passes out at the hilum, or near it, or at a point apparently provided by nature for that purpose, as in Canna, Commelina, &c. If the radicle has a coleorhiza or root-sheath, this is soon perforated by the radicle contained within it, which passes through the extremity; as in Grasses, and most monocotyledonous plants. The cotyledons either remain under ground, sending up their plumule from the centre, as in the Oak; or from the side of their elongated neck, as in Monocotyledons; or they rise above the ground, acquire a green colour and perform the ordinary functions of leaves, as in the Radish and most plants. In the Mangrove, germination takes place in the pericarp, before the seed falls from the tree; a long thread-like caulicle is emitted, which elongates till it reaches the soft mud in which such trees usually grow, where it speedily strikes root, and separates from its parent. Trapa natans has two very unequal cotyledons: of these, the larger sends out a very long petiole, to the extremity of which are attached the radicle, the plumule, and the smaller cotyledon (Mirbel). Cyclamen germinates like a Monocotyledon: its single cotyledon does not quit the seed till the end of germination; and its caulicle thickens into a fleshy knob, which roots from its base. The Cuscuta, which has no cotyledons, strikes root downwards, and lengthens upwards, clinging to any thing near it, and performing all the functions of a plant, without either leaves or green colour. In Monocotyledons, the cotyledon always remains within the seminal integuments, while its base lengthens and emits a plumule. In Cycas, which has two cotyledons, the seminal integuments open, and the radicle escapes.

It has already been seen, that, under certain circumstances, the vitality of seeds may be preserved for a very considerable length of time; but it is difficult to say what are the exact conditions under which this is effected. We learn from experiment that seeds will not germinate if placed *in vacuo,* or in an atmosphere of hydrogen, nitrogen, or carbonic acid; but no such conditions exist in nature,

and, therefore, it cannot be these agents which have occasionally preserved vegetable vitality in the embryo plant for many years.

The preservation of vitality in seeds depends upon the stability of the chemical compounds of which they consist. This appears to be the hinge upon which every thing turns. Before a seed is quite ripe its elements are highly unstable or liable to change, and the least alteration in the conditions to which they may be exposed will cause them either to germinate or perish. But when a seed is perfectly ripe its elements become comparatively stable or indisposed to change, and to induce germination is in proportion difficult, while those alterations which are succeeded by death are slow in taking effect. Dryness in all cases, and in some a perfect exclusion of atmospheric air, are found to be the conditions upon which the preservation of life in seeds mainly depends. Some seeds will live for a long time if gathered ripe and preserved quite dry; others will perish after a short time although kept dry, and these demand the exclusion of air in addition. Corn, Pulse, and, in general, farinaceous seeds, belong to the former, while all oily seeds, and such as contain much tannin, are to be classed in the latter series; apparently because of the great affinity of their compounds for oxygen. This explains why, under the same circumstances, one kind of seed will survive a voyage, and another dies. A man buys Corn, Peas, Beans, Nuts, Acorns, and Holly-berries, and sends them to the antipodes: the first three and the last survive the voyage: the others invariably perish.

The mode of packing seeds is generally such as to render this risk greater than it need be. Half dried seeds are placed in half dry papers, and the whole are inclosed in a tin case placed in the hold of a ship. There the temperature rises; the dampness present favours germination; growth commences; all the stable chemical compounds of the seeds are suddenly converted into unstable principles, and as growth cannot possibly go on, death ensues; last follows decay. The remedy is obvious. Great care in drying the seeds, and the papers they are packed in, and free ventilation in a cool

place, such as a coarse bag suspended to a nail in a cabin, counteract the dangers to which farinaceous and similar seeds are usually exposed. But with the second class such precautions are ineffectual. For oily seeds, Beech-mast, Acorns, Nuts, and grain of a similar nature, the exclusion of air is indispensable. The mode of securing this object is usually to enclose seeds in dry earth or sand *rammed hard;* or in charcoal powder, the whole covered with tin or put in a stout box; and no better common method seems to exist. It is, however, far from perfect, and therefore much disappointment occasionally attends its use. It is worth inquiring whether all seeds would not preserve their vitality most perfectly if kept in an atmosphere of carbonic acid, which would seem likely to oppose an effectual barrier to those changes which destroy seminal life.

In order to illustrate the circumstances under which the vitality of seeds is preserved accidentally for a long series of years, I cannot do better than give the substance of a statement published a year or two ago by Mr. Kemp, in the *Annals of Natural History,* vol. xiii. p. 89. This is one of the few instances in which the suspension of vitality in seeds for a very long period is unquestionable. This gentleman says that, having received some seeds which were found at the bottom of a sand-pit upwards of twenty-five feet in depth, he most carefully examined into all the circumstances of their discovery. They were first seen by a workman who was excavating the finer sand at the bottom of the pit, in a part which was rather undermined. The seeds were apparently of only two kinds; specimens of them, however, being sown produced Polygonum Convolvulus, Rumex Acetosella and an Atriplex.

The sand-quarry in question is described as being situated about a quarter of a mile west of Melrose, and at the height of between fifty and sixty feet above the nearest part of the Tweed. The seeds were mingled with some decayed vegetable fibres, and formed a layer resting upon another layer, eight inches in thickness, of fine sandy clay. This latter lay over a mass of gravel, which again rested on a great mound belonging to the boulder formation. This mound, which

extends about a mile along the middle of the valley, is about ninety feet in thickness, and Mr. Kemp believes was formed by the action of glaciers. It contains enormous angular blocks of rock, and others smoothed and distinctly scored in lines parallel to their longer axes. The layer of sandy clay, on which the seeds rested, was capped by upwards of twenty-five feet in thickness, of distinctly stratified sand, which has been largely quarried. The beds of sand vary in thickness and in fineness; sometimes they alternate with thin seams of impalpable clay, and sometimes they contain minute pebbles and fragments of carbonaceous decayed wood. The layers slope at an angle of fifteen degrees towards the valley, and in this direction they thin out; the upper layers extend further into the valley than the lower ones; the entire mass has a level top, and is capped by some thin beds of fine gravel. From these several facts, observes Mr. Kemp, and from the general aspect of the layers of sand, it is scarcely possible to doubt that the seeds were deposited by a river or torrent, at the point where it entered a sheet of water. "I had long been of opinion," he adds, "that the valley of the Tweed in this part must formerly have been occupied by a lake, at a period when a great trap dyke, 100 yards wide, which crosses the valley four miles lower down at Old Melrose, had not been worn through. By an accurate levelling I have ascertained that the layers of sand lie just beneath that level which a lake would hold if the barrier at Old Melrose were reclosed. A depression on the surface of the land can also be distinctly followed from the spot where the sand-quarry is situated, up the valley, to where it joins the bed of the existing river. I cannot doubt that the Tweed anciently flowed in this depression, and deposited on the borders of the lake the layers of sand where we now find them. It is certain that in the time of the Romans, about 2000 years since, no lake existed here; and when we reflect on the time necessary to have worn down the barrier of trap-rock and to have drained so large a lake, which must have stood at its highest level whilst the thin layers of sand were deposited over the bed with the vegetable remains, the antiquity of these seeds is truly astonishing, and it is most wonderful

that they should have retained their power of germination."

It seems probable that the circumstance which enabled them to do so was partly their original nature, they having belonged to what may be called the farinaceous series, and partly the exclusion of air by means of the beds of sand that gradually formed over them.

CHAPTER XII.

OF THE FOOD OF PLANTS.

PLANTS acquire food both by their roots and leaves; and there is reason to believe that there is little difference in the power possessed by these organs of taking it up. The largest part of the food of plants is, however, derived from the earth, and the air lying in its interstices, and is introduced into their system through the roots. The latter are, however, incapable of absorbing anything solid; fluid and gaseous matter only can pass through their spongelets. It is exclusively in the form of gaseous matter or of water that the nutritive ingredients of the soil are received by roots; not, however of pure water, which in fact does not exist in nature, but of water holding various solid matters in solution, the most remarkable and abundant of which are, potash, soda, magnesia, lime, alumina, silex, phosphates, and sulphates.

Soil in its natural state is filled with the remains of organic bodies, which decompose, and yield ammonia, or become converted into carbonic acid. In proportion to the abundance of these is soil fertile. Ammonia, and the carbonic acid incessantly forming below the surface of the earth, enter freely into the roots; mixing with water and such other principles as may already have been formed there, they become sap, ascend the stem, partly decompose to a certain extent as they pass along, giving, apparently, oxygen to the spiral vessels, which convey it into other parts of the system. When sap reaches the leaves, it liberates its oxygen more completely, and leaves its carbon to unite with the tissue of vegetation, or to enter into new combinations with water, atmospheric air, or other elements that it finds itself in contact with: whence proceed the gummy, amylaceous, resinous, oily, and other products peculiar to the vegetable kingdom.

It has been observed by a modern writer, "that, if the roots of a plant are placed in a close vessel, in distilled water, from which carbonic acid has been carefully expelled, the plant may increase a little in size, in consequence of the decomposition of the water, and the combination of its elements with the vegetable system; but it is only when carbonic acid is added, that the plant acquires its natural vigour and rate of growth. But if a plant is placed in solid carbon, and you water it with distilled water, it might as well be planted in powdered glass, until the carbon begins to combine with the oxygen of the air, and to form carbonic acid. Sir Humphry Davy placed a plant of Mint in water mixed with carbon in a state of impalpable powder, and he found that not a particle could enter the roots. If we look to the effects of manures, we shall find that in most cases, except when their object is to alter the state of the soil mechanically, or to act as stimulants, as is probably the case with sulphate of iron, their energy is in proportion to their capability of forming carbonic acid. Yeast, for instance, which is one of the most active manures we have, is so from possessing, beyond all other substances, the power of exciting fermentation, and thus of causing the formation of carbonic acid among the vegetable matter which lies buried in the soil.*

* Dr. Seller calculates the annual conversion of the carbon of organic matter into inorganic carbonic acid at not less than 600 millions of tons; and infers, on the most favourable aspect of the amount of soil over the earth's surface, that such an annual loss could not be withstood beyond 6000 years; and, on a less exaggerated assumption of its amount, probably very near the truth, that the waste would absorb the whole of the existing organic matter of the soil in about 740 years. Dr. Seller contends that the truth of these conclusions remains unaltered, even if it be conceded that much of the carbon of plants is drawn, not from the organic matter of the soil, but from the inorganic carbonic acid of the atmosphere, unless some inorganic source of their hydrogen and oxygen be at the same time admitted. He therefore regards Liebig's view of the inorganic nature of the food of plants as supported not merely by many special facts—for example, by the increase of the organic matter of the soil, often observed during the growth of plants,—but also by the general view of the earth's surface just taken, because there is nothing in its aspect to warrant the idea that its means of maintaining the organic kingdoms are declining with the rapidity indicated in the statements just made. Dr. Seller also examines Liebig's view of ammonia; first, as the sole source of the nitrogen of plants, and thereby of animals; second, as having its exclusive origin from the interior of the earth, and never from the nitrogen of the atmosphere. In regard to these statements he makes it appear,

"While, however, all experiments combine to prove that carbonic acid is the most essential of the elements upon which plants are nourished, it is necessary that the student should be aware that other species of matter are constantly taken into the system, and probably, therefore, contribute to their nutrition.

"Water is one of these. Although we know that a very large proportion of all the water absorbed by a plant is lost again by evaporation, yet the experiments of Théodore de Saussure have shown that a portion of it is actually solidified. He found that when plants are grown in a close vessel, in an artificial atmosphere, containing a little carbonic acid, the weight which the plant acquired in a given time was augmented, not only by the quantity of carbon produced by the decomposition of carbonic acid, but to a much more considerable extent, which could only be ascribed to its having fixed a considerable quantity of water; thus plants of the Periwinkle, which, in a vessel without carbonic acid, had gained $1\frac{3}{4}$ grain from water, acquired $5\frac{8}{10}$, when they were at the same time able to procure carbon. The same excellent observer has computed that, if we calculate with the utmost care all the weight which a plant can gain, by fixing carbon, by depositing earthy, saline, alkaline, metallic, and other matters which it borrows from the soil, we shall not be able to account for more than a twentieth part of the real weight of such a plant. The other nineteen-twentieths must, therefore, be fixed water. Whatever errors there may be in calculations of this nature, there cannot be much doubt that they are correct to so considerable an extent, as to oblige us to admit that water forms a considerable part of the solid tissue of plants; so that it would appear that, like minerals, plants have a water of crystallisation independently of their water of vegetation."

as there is no evidence of ammonia being thrown forth from the bowels of the earth at all times in quantity proportioned to the waste of it necessarily sustained at the surface by decomposition, as into uncombined hydrogen and nitrogen, that Liebig's view of ammonia infers the same limitation of the existence of the organic kingdoms to a few thousand years, as is deduced from the hypothesis of organic matter being the food of plants. Here, therefore, he dissents from Liebig, contending that ammonia must be produced from the nitrogen of the atmosphere, and showing the probability of what is taught by Professor Johnson, namely, that the nitrogen of nitrates, formed from the atmosphere, is fixed by plants, as well as the nitrogen of ammonia. *Annals of Natural History*, xv. 350.

It has already (p. 261.) been shewn that Messrs. Edwards and Colin have proved experimentally that plants decompose water by their vital force, fixing the hydrogen and parting with the oxygen, which combines with carbon, forming carbonic acid.

As it has been supposed that all the oxygen given off by plants is produced by the decomposition of carbonic acid, it has been inferred that, if the water which is consumed by plants is ever decomposed, it is in the formation of the various secretions which contain more oxygen (acids), or more hydrogen (oils), than water: but, as the greater part of vegetable substances, such as gum, sugar, fæcula, &c., contain oxygen and hydrogen in the same proportions as water, it has been thought that the greater part is undecomposed and simply fixed; but the experiments of Edwards and Colin, above referred to, prove the contrary.

It was formerly thought that nitrogen, or azote, has nothing to do with the nutrition of plants; and that, in those cases where it was met with, it was merely in a state of separation from the atmospheric air which had been inhaled and deprived of oxygen and carbonic acid. But M. Boussingault long since proved, that it is in fact a constant element of vegetation, most concentrated in seeds, to the maturation of which it is essential, and dispersed through the other parts of the tissue. (*Comptes rendus*, vi. 105.)

In the form of carbonate of ammonia it is greedily taken up by plants, which obtain it naturally through the intervention of rain water or snow. It is found everywhere in tissues, very abundantly in the youngest parts of plants, sparingly in the oldest, and probably contributes to the rapid decay of the former, as it does to that slower rotting process which is observed in timber. Chemists have in fact ascertained that by washing away the soluble azotised matter of timber, its power of resisting decay is much increased. Mr. Rigg finds the youngest parts of plants richest in nitrogen, the germ of Peas and Beans containing by weight about 200 parts of that gas for 1000 parts of carbon, while the cotyledons contain only from about 100 to 140 parts. He is disposed to believe

that those seeds of the same kind, which contain the largest quantity of nitrogen, germinate the earliest. Alburnum he finds to contain more nitrogen than duramen, and fast-growing timber more than slow-growing, whence he infers that nitrogen exercises its influence in causing decomposition. The latter opinions he considers to be rendered still more probable by the proportion of nitrogen found in different species of wood, *cæteris paribus:* thus in satin wood and Malabar teak, both timber of great durability, the quantity of nitrogen is almost inappreciable; in Dantzic and English oak, the quantity is also very small; in American birch which soon decomposes, nitrogen is found in large quantities. Mr. Rigg finds nitrogen in large quantities in Vine leaves when they first make their appearance: as they are developed it decreases in proportional quantity; is in excess during the period of most rapid growth, and towards the close of the year it is comparatively small. He states the full-blown petals of the Rose to contain 24 parts of nitrogen in 1000 of carbon, while the unexpanded and central petals contain 66 parts. Mr. Rigg has also considered the evolution of nitrogen during the growth of plants, and the sources from which they derive that element. He states that his enquiries all tend to prove that nitrogen is evolved during the healthy performance of the functions of plants; that the proportion which it bears to the oxygen given off is influenced by the sun's rays; but that owing to the necessary exclusion of the external atmosphere during the progress of experiments, it is impossible, with any degree of accuracy, to calculate the volume of these evolved gases during any period of the growth of plants in their natural state. If to this indefinite quantity of nitrogen given off by plants, there be added that definite volume incorporated into their substance, the question arises, whence do plants derive their nitrogen, and does any part of it proceed from the atmosphere? This problem Mr. Rigg has endeavoured to solve by a series of tabulated experiments upon seeds and seedling plants, the result of which is a large excess of nitrogen in the latter, and under such circumstances of growth that he is compelled to fix upon the atmosphere as its source. He has also arrived at the conclusion, that the

differences which we find in the germination of seeds and the growth of plants in the shade and sunshine, are due in a great measure to the influence of nitrogen.

According to Payen (*Comptes rendus*, viii. 60.), those manures are the most efficient which are richest in nitrogen, for he considers that plants are generally able to obtain, in most cultivated soils, a sufficient supply of the other principles necessary to their existence, without the addition of manure. But this does not quite agree with an assertion of Boussingault, that although some plants rob the air of a considerable quantity of nitrogen, yet others do not assimilate it at all. (*Ib.* 55.)

The solid matters found in the ashes of plants vary greatly from species to species, and are of different degrees of importance in different cases. This will be evident from the following table, which indicates the proportion of the more common substances discovered by chemists in 100,000 parts of the dried plant. The first ten analyses are given upon the authority of Sprengel; the next eight are taken from Professor Edward Solly's Rural Chemistry :—

	Silica.	Lime.	Potash.	Soda.	Magnesia.	Alumina.	Phosphoric Acid.	Sulphuric Acid.	Iron.
Oat straw .	4584	152	870	2	22	6	12	72	2
Buckwheat straw . .	140	704	332	62	1292	26	288	217	15
Bean straw .	220	624	1656	50	209	10	226	134	7
Pea straw .	996	2730	235	. . .	342	60	240	337	20
Potato straw	801	2918	138	. . .	488	52	32	245	58
Rape straw .	80	810	883	550	121	90	382	517	—
Oak leaves .	1515	2307	1	. . .	183	85	190	91	24
Heath . . .	582	518	94	200	164	45	15	102	53
Ferns . . .	1040	433	1050	370	152	52	60	95	150
Ash sawdust .	18	127	121	189	32	?	8	17	?
Wheat. . .	2870	240	20	29	32	90	170	37	—
Barley . . .	3856	554	180	48	76	146	160	118	14
Maize . . .	2708	652	189	4	236	6	54	106	4
Buckwheat .	140	704	332	62	1292	26	288	217	15
Flax . . .	20	230	510	. . .	480	2	118	66	10
Beans . . .	220	624	1656	50	209	10	226	34	7
Potato . . .	801	2928	138	?	488	52	32	245	58
Cabbage . .	210	1747	2370	1154	22	17	785	959	8

Such facts show that while Lime, Potash, and Soda are an important constituent of Cabbages: they are of little moment in Flax; that Silica is a great ingredient in Corn, but of small amount in Buckwheat, and so on. But the constant presence in every case of nearly all the inorganic matters mentioned in the foregoing table leads to the conclusion that they are indispensable adjuncts to Water, carbonic acid, and nitrogen in sustaining vegetable life.

Silica. This substance is extremely abundant in some plants, and comparatively rare in others. They no doubt obtain it from the soluble silicates, especially that of potash, which are found everywhere in soil. In the Bamboo it forms the hard varnish that guards the whole surface, and is occasionally excreted in its hollow stems in the form of the opaline substance called Tabasheer (Silex 70, Potash and Lime 30—*Vauquelin*). It is the varnish and skeleton of grasses and many other plants, occupying sometimes a definite and invariable position in their structure, as in Equisetum. According to the Rev. J. B. Reade (*Taylor's Magazine,* vol. lxvii. p. 414), some vessels are actually composed of silica, no trace of vessel remaining if that substance is removed. Göppert has also shown that mineral matter artificially introduced into plants will take entire possession of them, destroying or displacing the vegetable matter, without altering their tissue or their structure. (*Comptes rendus,* iii. 656).

Lime. This matter may be regarded as always present wherever water that has passed through soil has access. It must therefore be universally in contact with the roots of plants, to some of which it is doubtless constitutionally indispensable; and hence it is that it so constantly occurs in the ashes of plants. Very copious details regarding its action and importance will be found in *Johnson's Lectures on Agricultural Chemistry.*

Magnesia, although so often found in the ashes of plants, has been sometimes looked upon as injurious to vegetation; but this is certainly not true, unless it is present in a caustic state, and in great excess. Professor Giobert states that native magnesia is found abundantly in the environs of Castellamonte and of Baldissero, the soils of which exhibit

a vigorous vegetation. In many districts of Piedmont, where the bi-carbonate of lime and of magnesia are abundant, the cultivated lands produce beautiful plants. Hence he concludes, 1st, that native carbonate of magnesia is not injurious to plants; 2nd, that, on account of the solubility of magnesia in an excess of carbonic acid, that earth may exercise an action analogous to that of lime; 3rd, that magnesian soils may be fertile when the necessary manures are employed. M. Abbene is of opinion, from comparative experiments, that the influence of magnesia on vegetation is analogous to that of lime. He states that native magnesia is not injurious to germination, vegetation, or fructification, but on the contrary, is favourable to those functions. Being soluble in an excess of carbonic acid, it has an effect on vegetation similar to that of lime. When land contains magnesia not sufficiently carbonated, the defect is remedied by manure, whose decomposition furnishes the necessary supply of carbonic acid. When lime and magnesia co-exist, the former is absorbed in preference, on account of its greater affinity for carbonic acid; when magnesian lands are barren, it is not to the magnesia that the sterility must be attributed, but to the cohesive state of its parts, to the want of manure, of clay, or of other matters, to the presence of a large quantity of oxide of iron, &c.

Alkalies. All plants contain alkalies, in combination with organic acids: and much probability attaches to the opinion of Liebig that their office in a physiological point of view is to form bases for those acids. In the majority of land plants Potash predominates, in marine or maritime plants, Soda. Liebig asserts that the proportion of these bases in a given plant is invariable, but that *any one may be substituted for another,* the action of all being the same. Since, however, the quantity of alkali contained in different species is variable, one species of plant will require a more alkaline soil than another. The perfect development of a plant is therefore dependent on the presence of alkalies or alkaline matter; for when these substances are totally wanting, growth will be arrested; and when they are deficient, it must be impeded in proportion.

It is, however, by no means certain that the alkalies may be substituted for each other in maintaining vegetation. The following case, mentioned by Professor Moretti, seems to indicate the contrary:—

Let two pots of the same earth, under circumstances the same in all respects, be planted, the one with common Pellitory (*Parietaria officinalis*), the other with common Saltwort (*Salsola Kali*). Let them be both watered equally with two different solutions, the one of salt (*muriate of soda*), the other of saltpetre (*nitrate of potash*). Although each will have its roots equally exposed to the salt and saltpetre, yet the Pellitory will be found to contain saltpetre without salt, and the Saltwort, salt without saltpetre. It therefore seems clear that the roots of Saltwort refuse to imbibe saltpetre, and those of Pellitory to feed on salt. It is true that the above fact may be apparently explained by supposing that Saltwort rejects potash, and Pellitory soda, after they have imbibed them; but if this really happens, we nevertheless seem forced to conclude that soda is the alkali necessary to Saltwort, and potash that essential to Pellitory.

About the general importance of alkalies to plants there seems, however, to be no room for doubt, and the discovery of Liebig explains many things that were inexplicable before. When we say that a plant becomes tired of a soil, and find that manuring fails to invigorate it, the destruction of alkalies in the soil, and the want of a sufficient supply of those bases in the manure, seem to offer a solution of the enigma. And in like manner the gradual decay of trees in public squares and promenades, where the soil is incessantly robbed of alkaline matter, for the sake of neatness, may probably be ascribed to the same cause. So also the injurious action of weeds is explained by their robbing the soil of that particular kind of food which is necessary to the crops among which they grow. Each will partake of the component parts of the soil, and in proportion to the vigour of their growth, that of the crop must decrease; for what one receives the others are deprived of. "Plants will, on the contrary, thrive beside each other, either when the substances necessary for their growth, which they extract from the soil, are of different

kinds, or when they themselves are not both in the same stages of development at the same time. On a soil, for example, which contains potash, both Wheat and Tobacco may be reared in succession, because the latter plant does not require phosphates, salts which are invariably present in Wheat, but requires only alkalies and food containing nitrogen." This seems to be the true explanation of the rotation of crops.

"In order to apply these remarks," says Dr. Liebig, "let us compare two kinds of tree, the woods of which contain unequal quantities of alkaline bases, and we shall find that one of these grows luxuriantly in several soils upon which the others are scarcely able to vegetate. For example, 10,000 parts of Oak-wood yield 250 parts of ashes; the same quantity of Fir-wood only 83, of Lime-wood 500, of Rye 440, and of the herb of the Potato-plant 1500 parts. Firs and Pines find a sufficient quantity of alkalies in granitic and barren sandy soils, in which Oaks will not grow; and Wheat thrives in soils favourable for the Lime-tree, because the bases which are necessary to bring it to complete maturity exist there in sufficient quantity. A harvest of grain is obtained every thirty or forty years from the soil of the Luneburg heath, by strewing it with the ashes of the Heath-plants (*Erica vulgaris*) which grow on it. These plants, during the long period just mentioned, collect the potash and soda, which are conveyed to them by rain-water; and it is by means of these alkalies that Oats, Barley, and Rye, to which they are indispensable, are enabled to grow on this sandy heath."

Alumina. The minute quantity of this substance which occurs in plants, renders it doubtful whether its presence is more than accidental; and its importance to soil is usually regarded as dependent upon its mechanical action. In some plants it does not occur at all, as in the Scotch fir, according to the Prince of Salm Hostmar; this chemist ascertained, however, that the statement of Berzelius is correct, that alumina is found in Lycopodium complanatum and Helleborus niger. In the former he found more than thirty-eight per cent., although a mere trace was detected in the ashes of a Juniper bush growing close to the Lycopod. The Prince supposes

that the roots of plants containing alumina, either exert a peculiar catalytic action upon the aluminous compounds with which they are in contact, or excrete an acid; for were the aluminous constituents of the soil soluble *per se* in the fluids of the soil, they would also be absorbed by other plants.—(*Chemical Gazette*, 1847. p. 307.)

Phosphates. All plants contain phosphoric acid. It is from plants that animals obtain it. It does not, however, exist in a free state in nature, but in the condition of phosphates, in which form it is found in plants. It is one of the most essential constituents of soils; probably gives much of their true value to manures; and its absence would be accompanied by sterility. It is, however, of more importance to some plants, as Crucifers, than to others, as Cereals, as will be apparent from the preceding table.

Sulphates. It would seem that sulphuric acid in a state of combination is also universally present in plants, varying like phosphoric acid in its proportional quantity. Crucifers abound in it, while very little is found in Oak leaves or in Ash timber. Hence the sulphates of soda, lime, and magnesia, and substances evolving sulphuretted hydrogen, are all important as manures.

Oxides of iron, manganese, &c., are very often present in plants. It is, however, doubtful whether they usually exercise any influence in the functions of vegetation. Professor Johnson supposes them to enter the roots, "either in the state of soluble sulphate or of carbonate dissolved in carbonic acid, or of some other of those numerous soluble compounds with organic acids, which may be expected to be occasionally present in the soil."

In addition to the food thus supplied to plants from without, a very abundant source of nutrition to the young parts is derived from their own secretions, the most important of which is starch. The purpose which nature intends this almost universally diffused substance to answer, in the system of vegetation, is essentially nutritive. It is formed in plants soon after their parts become organised, and it collects there till in some instances, such as albumen, tubers, rhizomes,

and the cellular part of endogenous stems, it forms the principal part of the mass. In such cases it is ready to be chemically changed at a fitting period, and to become the food of the germinating embryo, or of young stems and leaves. According to M. Payen, it is enabled to execute this important purpose, by virtue of its gradual solution by water and diastase, which convert it into dextrine and sugar, and thus render it capable of percolating the surrounding tissue, and passing from chamber to chamber of parenchym. (*Mémoire sur l' Amidon*, p. 131.)

In his investigation of the anatomy of Cycads, Professor Morren arrived at a fact of great interest in Vegetable physiology. It is well known that all these plants yield an abundance of gum, which flows from them freely in a liquid state when wounded; the author ascertained the correctness of Professor Meyen's statement, that the flow of such matter takes place in special channels, *i. e.*, in long fistulæ, whose walls are built up of cellular tissue. It is usually supposed that gum is a secretion from the leaves of plants, and that it consequently flows from above downwards; it has been even compared to the blood, and regarded as the most pure, and most essential part of their nutritive matter. Professor Morren has, however, proved by some well conducted experiments, that in Cycads at least, the gum moves from below upwards, and that it arises in the stem, whence it mounts into the leaves. The author therefore suspected that gum is an ulterior elaboration of the starch lodged in the trunk, and that such elaboration is excited, or brought about or at least assisted, by some acid, probably supplied by the leaves themselves to the trunk; a suspicion eventually confirmed by chemical investigation.

M. de Coninck, Professor of Chemistry at Liége, analysed the leaves of Cycas revoluta, and ascertained that they contained 1° Muriatic acid, probably combined with soda or potash; 2° Oxalic acid, probably free; and 3° Oxalate of lime, forming the principal part of the solid exterior layer of the leaves; a very interesting fact, inasmuch as superficial indurations of plants have always hitherto been ascribed to the presence of silex. From these facts M. Morren concludes

that in Cycads gum is formed at the expense of the starch of the stem, and that such a change is effected by the action of the free oxalic acid secreted in the leaves.

We are, therefore, to understand hereafter that gum is a form of the nutritive matter of plants; that, instead of being the result of vegetable digestion, it is a principle created by nature for their crude food; that one at least, if not the principal of the functional purposes for which starch is universally dispersed through the tissue of plants, is in order that it may be everywhere ready for conversion into gum; and finally that it is in the form of gum that starch passes through the sides of the tissue in which its granules were originally generated.

Fixed as plants are to the soil, deprived of volition, and incapable of removing their highly absorbent roots from what is hurtful to them, except with extreme slowness, it appears scarcely probable that they should have any power of selecting their food; on the contrary, the facility with which they are poisoned would seem to show their helplessness in this respect. But, if roots are made to grow in coloured infusions, it is said that they take up only the colourless parts, leaving the coloured behind; and we know that if an apple tree is planted in a piece of ground in which another apple tree has been growing many years, the new plant will languish and become unhealthy, whatever quantity of manure, that is of new food, may be offered to its roots. This last fact is accounted for upon the supposition that the soil contains some peculiar principles which are necessary to the health of an apple tree, and that the old tree having selected for its own consumption all that the soil contained, has left none behind it for the new comer. It has been, however, demonstrated by Daubeny, that plants have, to a certain extent, a power of selection by their roots. He found that when barley was watered with distilled water, containing in every two gallons two ounces of nitrate of strontian, not a trace of that earth could be detected in the ashes of the plants; and when Lotus tetragonolobus was treated in a similar manner, except that only two ounces of nitrate of strontian were dissolved in

ten gallons of distilled water, although the whole of that quantity was expended upon them, a minute examination demonstrated that the stems contained no trace whatever of strontian, although a small portion appeared to be present in, *or at least adherent to,* the roots. By other experiments it was ascertained, that the strontian was not in these cases first received into the system, and afterwards rejected through the roots; for when the roots of a Pelargonium were divided into two nearly equal bundles, one of which had its extremity immersed in a glass containing a weak solution of nitrate of strontian, the other in one containing pure distilled water, after the lapse of a week the water in the second glass was tested, but no strontian could be discovered in it, although a single grain in one pint would have been readily detected. Hence it appears, "that plants do possess, to a certain extent at least, a power of selection by their roots, and that the earthy constituents which form the basis of their solid parts are determined as to *quality* by some primary law of nature, although their *amount* may depend upon the more or less abundant supply of the principles presented to them from without." (*Linn. Trans.* xvii. 266.)

Bouchardat, however, maintains, that plants have no power of selection. He thinks that the experiments of Théodore de Saussure, who maintained the contrary, are not sufficiently free from all chances of error to be conclusive. The way in which the experiments of Théodore de Saussure were made may be stated in a few words. He dissolved in 793 cubic centimetres of water two or three different salts, each weighing 637 milligrammes; he analysed the residue of the solution when it was reduced one-half by absorption by the roots of the plants. The quantity of salts contained in the residue, minus that which the liquid contained before the introduction of the plants, indicated the quantity of salts absorbed. Théodore de Saussure saw that with several salts this quantity was very unequal; thus, to cite only one example, in a mixed solution of nitrate of lime and muriate of ammonia, a Polygonum absorbed two of nitrate of lime, and fifteen of muriate of ammonia.

The differences were particularly great with the soluble

salts of lime; their absorption appears infinitely less easy than that of several other salts; but the following experiment throws much doubt on the conclusion to be drawn from the facts cited by Théodore de Saussure.

In a solution in distilled water containing one gramme of sulphate of soda, and one gramme of chloride of sodium to the litre, I planted a Polygonum persicaria, and when half the solution was absorbed, I examined the residue, and found in it, besides the oxalate of ammonia, a notable quantity of lime, which did not exist in it previously, and which had been furnished by the vegetable.

This then is one capital cause of error which escaped Théodore de Saussure. When a vegetable is immersed in an aqueous solution, there is not a pure and simple absorption of the solution, but a double current is formed. As the salt of the solution passes into the plant, so the salts of the plant arrive in the solution. This is the principle which M. Dutrochet has so well developed in his excellent investigations on Endosmosis.

There is a strong and a weak current, but always a double current, and not a pure and simple absorption. This cause of error is very important, for Théodore de Saussure operated only upon 637 milligrammes, diminished by the fact of the absorption alone, and he did not at all attempt, in his analysis, as may be seen at page 255 of his *Recherches sur la Végétation*, to find any other principles than those which he wished to estimate; moreover he has not indicated the weight of the plants he employed.

To avoid, as far as possible, the chances of error caused by the excretions of the roots, I thought that plants should be chosen which, living a considerable time in water, might, by a very long vegetation, be brought into such a condition as no longer to yield any fixed salt to the distilled water, and which would yet possess a marked power of absorption. Mentha aquatica seemed, from numerous previous experiments, to fulfil these conditions much better than the Polygonum Persicaria and Bidens cannabina, selected by Théodore de Saussure. The following is the manner in which my experiments were made. Branches of mint, furnished with

numerous adventitious roots, which had lived in pure water for more than six months, were placed in flasks containing distilled water, which was renewed every five days. When the re-agents did not indicate any foreign salt in this water, I made with these plants precisely the same experiments as Théodore de Saussure had done, and I then found that a vegetable freely immersed by its roots in a very dilute solution of several salts, having no chemical action on its tissues, absorbs all the substances contained in that solution in equal proportions. (*Annals of Natural History*, xviii. 134.)

But the following very common experiment seems to me to show conclusively that plants do select the food presented to their roots. If a grain of wheat and a garden pea are sown in the same soil, side by side, are watered with the same water, and treated in all respects alike, it will be found at the end of their growth, that the wheat has taken a large quantity of silica (2870) from the soil, while the pea has taken far less (1000); and that for 240 of lime in the wheat, there are 2730 in the pea. The inference seems irresistible that the Pea refuses to take up the silicates on which the Wheat plant feeds, and selects lime which is equally indifferent to the Wheat.

It must be obvious, that the *exhaustion* of soil by plants means their having consumed all the nutritive particles that it contains. What are those nutritive particles? That depends upon the nature of the plants; when land is exhausted of phosphates it ceases to bear turnips, but will carry corn; when silica is abstracted it will bear turnips, but not corn. In like manner the absence of potash, soda, lime, magnesia, iron, sulphur, &c., will be injurious to those plants to which these substances are peculiarly necessary. Carbonic acid is indispensable to the formation of vegetable tissue; but it is only in the presence of nitrogen that it can be decomposed. Therefore the absence of carbonic acid and nitrogen produces exhaustion of the soil.

Thaer and Boussingault both agree in considering the efficiency of manures dependent in a great measure upon their animalised nature, or their power of adding nitrogen to

vegetable tissue ; and, consequently, it is probable that the exhaustion of soil does not depend merely upon the destruction of carbonaceous matter, but also upon the consumption of the azotised matter contained in it. This is a most important fact to consider, in attempting to estimate the action of manures. (*Comptes rendus*, vi. 106.)

Those who wish to understand the modern opinions concerning the theory of manures should consult De Candolle's *Physiologie*, p. 1278, and the works of Payen, Boussingault, Thaer, Liebig, Sprengel, Hlubek, Johnson, Dana and Edward Solly.

CHAPTER XIII.

OF DIGESTION.

After food is received into the system of a plant, it is gradually conveyed to the leaves, where it becomes decomposed or digested. It is probable that, in its passage through the stem, it undergoes some kind of decomposition, leaving a portion of its water and carbon fixed among the tissue; but it is principally in the leaves that it is altered. By the time, however, that it has arrived in these organs, it is by no means in the same state as when it entered the roots; but it becomes altered in its nature, and in its specific gravity, by the addition of what soluble matter it meets with in its progress, as has been proved experimentally by Knight.

The alteration that the fluids of plants undergo in their leaves appears to consist in parting with superfluous water by perspiration; in decomposing water, ammonia, and carbonic acid; and in assimilating the various matters which are left behind. The causes of these actions are believed to be, light, and the atmospheric dryness which light produces.

According to De Candolle, it is light alone to which PERSPIRATION and the suction of fluids by the roots are to be ascribed. He says, "If you select three plants in leaf, of the same species, of the same size, and of the same strength, and place them in close vessels, one in total darkness, the other in the diffused light of day, and the third in the sunshine, it will be found that the first pumps up very little water, the second much more, and the third a great deal more than either. These results vary according to species and circumstances; but it uniformly happens that plants in the sun absorb more than those in diffused light, and the latter more than those in darkness; the last, however, pumping up something.

If, again, we take three similar plants, and, preventing their absorption by the roots, after weighing them carefully, place them in three similar situations, we shall find that the plant exposed to the sun has lost a great quantity of water, that in common daylight a less amount, and that which was in total darkness almost nothing."

It is, however, to be supposed, that light is, to a certain extent, in these cases, a remote, as well as immediate, cause of perspiration: for we cannot apply solar light to plants without heating and rarefying their atmosphere. It is a well-known fact, that plants perspire in a sitting-room the air of which is constantly dry, but which is but imperfectly illuminated, so much more than in the open air exposed to the direct rays of the sun, that it is impossible to keep many kinds of plants alive in such a situation.

The admirable experiments of Hales, recorded in his *Vegetable Staticks*, demonstrate not only the fact of perspiration taking place, but its amount, and with what external influences it is connected.

"July 3, 1724, in order to find out the quantity imbibed and perspired by the Sunflower, I took a garden-pot, with a large Sunflower, $3\frac{1}{2}$ feet high, which was purposely planted in it when young. I covered the pot with a plate of thin milled lead, and cemented all the joints fast, so as no vapour could pass, but only air, through a small glass tube, nine inches long, which was fixed purposely near the stem of the plant, to make a free communication with the outward air, and that under the leaden plate. I cemented also another short glass tube into the plate, two inches long and one inch in diameter. Through this tube I watered the plant, and then stopped it up with a cork; I stopped up also the holes at the bottom of the pot with corks. I weighed this pot and plant morning and evening, for fifteen several days, from July 3 to August 8, after which I cut off the plant close to the leaden plate, and then covered the stump well with cement; and upon weighing found there perspired through the unglazed porous pot, two ounces every twelve hours' day, which being allowed in the daily weighing of the plant and

pot, I found the greatest perspiration of twelve hours in a very warm dry day, to be one pound fourteen ounces; the middle rate of perspiration, one pound four ounces. The perspiration of a dry warm night, without any sensible dew, was about three ounces; but when any sensible, though small dew, then the perspiration was nothing; and when a large dew, or some little rain in the night, the plant and pot were increased in weight two or three ounces. N.B. The weights I made use of were avoirdupoise weights. I cut off all the leaves of this plant, and laid them in five several parcels, according to their several sizes, and then measured the surface of a leaf of each parcel, by laying over it a large lattice made with threads, in which the little squares were half of an inch each; by numbering of which I had the surface of the leaves in square inches, which, multiplied by the number of the leaves in the corresponding parcels, gave me the area of all the leaves; by which means I found the surface of the whole plant, above ground, to be equal to 5616 square inches, or 39 square feet.

I dug up another Sunflower, nearly of the same size, which had eight main roots, reaching fifteen inches deep and sideways from the stem. It had besides a very thick bush of lateral roots, from the eight main roots, which extended every way in a hemisphere, about nine inches from the stem and main roots.

In order to get an estimate of the length of all the roots, I took one of the main roots with its laterals, and measured and weighed them, and then weighed the other seven roots, with their laterals, by which means I found the sum of the length of all the roots to be no less than 1448 feet.

And supposing the periphery of these roots at a medium, to be $\frac{1}{76}$ of an inch, then their surface will be 2286 square inches, or 15·8 square feet; that is, equal to $\frac{3}{8}$ of the surface of the plant above ground. If, as above, twenty ounces of water, at a medium, perspired in twelve hours' day (*i. e.*), thirty-four cubic inches of water (a cubic inch of water weighing 254 grains), then the thirty-four cubic inches divided by the surface of all the roots, is = 2286 square inches; (*i. e.*) $\frac{34}{2286}$ is = $\frac{1}{67}$; this gives the depth of water

imbibed by the whole surface of the roots, viz., $\frac{1}{67}$ part of an inch. And the surface of the plant above ground, being 5616 square inches, by which, dividing the thirty-four cubic inches, viz., $\frac{34}{5616} = \frac{1}{165}$, this gives the depth perspired by the whole surface of the plant above ground, viz., $\frac{1}{165}$ part of an inch. Hence, the velocity with which water enters the surface of the roots to supply the expense of perspiration, is to the velocity with which the sap perspires, as 165 : 67, or as $\frac{1}{67} : \frac{1}{165}$, or nearly as 5 : 2.

The area of the transverse cut of the middle of the stem is a square inch; therefore the areas, on the surface of the leaves, the roots, and stem, are 5616, 2286·1.

The velocities, in the surface of the leaves, roots, and transverse cut of the stem, are gained by a reciprocal proportion of the surfaces.

$$\text{Area of} \begin{cases} \text{leaves} = 5616 \\ \text{roots} = 2286 \\ \text{stem} = 1 \end{cases} \Bigg| \text{velocity} \Bigg| \begin{cases} = \frac{1}{5616} \\ = \frac{1}{2286} \\ = 1 \end{cases} \text{or as} \begin{cases} \frac{1}{165} \text{ inch.} \\ \frac{1}{67} \text{ inch.} \\ 34 \text{ inch.} \end{cases}$$

Now, their perspiring thirty-four cubic inches in twelve hours' day, there must so much pass through the stem in that time; and the velocity would be at the rate of thirty-four inches in twelve hours, if the stem were quite hollow. In order, therefore, to find out the quantity of solid matter in the stem, July 27th, at 7 A.M., I cut up, even with the ground, a Sunflower; it weighed three pounds in thirty days; it was very dry, and had wasted in all, two pounds four ounces; that is, $\frac{3}{4}$ of its whole weight. So here is a fourth part left for solid parts in the stem, (by throwing a piece of green Sunflower stem into water, I found it very near of the same specific gravity with water,) which filling up so much of the stem, the velocity of the sap must be increased proportionally, viz., $\frac{1}{3}$ part more, (by reason of the reciprocal proportion,) that thirty-four cubic inches may pass the stem in twelve hours; whence its velocity in the stem will be $45\frac{1}{3}$ inches in twelve hours, supposing there be no circulation nor return of the sap downwards. If there be added to 34, (which is the least velocity,) $\frac{1}{3}$ of it = $11\frac{1}{3}$, this gives the greatest velocity, viz., $45\frac{1}{3}$. The spaces being as 3 : 4, the

velocities will be 4 : 3 : : 45$\frac{1}{3}$: 34. But if we suppose the pores in the surface of the leaves to bear the same proportion, as the area of the sap vessels in the stem do to the area of the stem, then the velocity, both in the leaves, root, and stem, will be increased in the same proportion.

" From July 3rd to August 3rd. I weighed, for nine several mornings and evenings, a middle-sized Cabbage plant, which grew in a garden-pot, and was prepared with a leaden cover, as the Sunflower. Experiment 1st. Its greatest perspiration in twelve hours' day, was 1 pound 9 ounces; its middle perspiration 1 pound 3 ounces = 32 cubic inches. Its surface 2736 square inches, or 19 square feet. Whence dividing the 32 cubic inches by 2736 square inches, it will be found that a little more than the $\frac{1}{86}$ of an inch depth perspires off its surface in twelve hours' day. The area of the middle of the Cabbage stem is $\frac{100}{156}$ of a square inch; hence the velocity of the sap in the stem, is to the velocity of the perspiring sap, on the surface of the leaves, as 2736 : $\frac{100}{156}$: : 4268 : 1. for $\frac{2736 \times 156}{100}$ = 4268. But if an allowance is to be made for the solid parts of the stem, (by which the passage is narrowed,) the velocity will be proportionably increased. The length of all its roots 470 feet, their periphery at a medium $\frac{1}{22}$ of an inch, hence their area will be 256 square inches nearly; which being so small, in proportion to the area of the leaves, the sap must go with near eleven times the velocity through the surface of the roots, that it does through the surface of the leaves. And setting the roots at a medium at twelve inches long, they must occupy a hemisphere of earth two feet diameter, that is, 2·1 cubic feet of earth. By comparing the surfaces of the roots of plants, with the surface of the same plant above ground, we see the necessity of cutting off many branches from a transplanted tree; for, if 256 square inches of root in surface was necessary to maintain this Cabbage in a healthy natural state, suppose, upon digging it up, in order to transplant, half the roots be cut off (which is the case of most young transplanted trees), then it is plain that but half the usual nourishment can be carried up through the roots on that account; and a very much less proportion on account of the small hemisphere of earth the new planted

shortened roots occupy; and on account of the loose position of the new-turned earth, which touches the roots at first but in few points. This (as well as experience) strongly evinces the great necessity of well-watering new plantations.

"From July 29th to August 25th I weighed for twelve several mornings and evenings, a Paradise stock Apple-tree, which grew in a garden-pot, covered with lead, as the Sunflower: it had not a bushy head full of leaves, but thin spread, being in all but 163 leaves; whose surface was equal to 1589 square inches, or 11 square feet + 5 square inches. The greatest quantity it perspired in twelve hours' day, was 11 ounces, its middle quantity 9 ounces, or $15\frac{1}{2}$ cubic inches. The $15\frac{1}{2}$ cubic inches perspired, divided by the surface, 1589 square inches, gives the depth perspired off the surface in twelve hours' day, viz., $\frac{1}{104}$ of an inch. The area of a transverse cut of its stem, $\frac{1}{4}$ of an inch square, whence the sap's velocity here, will be to its velocity on the surface of the leaves as $1589 \times 4 = 6356 : 1$.

"July 27th. I fixed an Apple-branch, 3 feet long, $\frac{1}{2}$ inch diameter, full of leaves and lateral shoots, to a tube, 7 feet long, $\frac{5}{8}$ diameter. I filled the tube with water, and then immersed the whole branch as far as over the lower end of the tube, into a vessel full of water. The water subsided six inches the first two hours (being the first filling of the sap vessels), and 6 inches the following night, 4 inches the next day, and 2 + $\frac{1}{2}$ the following night. The third day in the morning, I took the branch out of the water, and hung it, with the tube affixed to it, in the open air; it imbibed this day 27 + $\frac{1}{2}$ inches in twelve hours. This experiment shows the great power of perspiration; since, when the branch was immersed in the vessel of water, the seven feet column of water in the tube, above the surface of the water, could drive very little through the leaves, till the branch was exposed to the open air. This also proves that the perspiring matter of trees is rather actuated by warmth and so exhaled, than protruded by the force of the sap upwards."

Light is, however, to all appearance, the exclusive cause of the decomposition of carbonic acid. It was long since remarked by Priestley, that, if leaves are immersed in water and

placed in the sun, they part with oxygen. This fact has been subsequently demonstrated by a great number of curious experiments, to be found in the works of Ingenhouz, Saussure, Senebier, and others. Saussure found that plants in cloudy weather, or at night, inhaled the oxygen of the surrounding atmosphere, but exhaled carbonic acid if they continued to remain in obscurity. But, as soon as they were exposed to the rays of the sun, they respired the oxygen they had previously inhaled, in about the same quantity as they received it, and with great rapidity. Dr. Gilly found that grass leaves exposed to the sun in a jar for four hours produced the following effect:—

At the beginning of the experiment there were in the jar:—		At the close of the experiment there were:—	
Of nitrogen	10·507	Of nitrogen	10·507
Of carbonic acid	5·7	Of carbonic acid	·37
Of oxygen	2 793	Of oxygen	7·79
	19·000		18·667

Heyne tells us that the leaves of Bryophyllum calycinum, in India, are acid in the morning, tasteless at noon, and bitter in the evening; Link himself found that they readily stained litmus paper red in the morning, but scarcely produced any such effect at noon. The same phenomenon is said also to occur in other plants, as Kleinia ficoides, Sempervivum arboreum, &c. This stain in the litmus paper could not have arisen from the presence of carbonic acid, as that gas will not alter blue paper, but it must have been caused by the oxygen inhaled at night. "If," says De Candolle, "two plants are exposed, one to darkness and the other to the sun, in close vessels, and in an atmosphere containing a known quantity of carbonic acid, and are removed at the end of twelve hours, we shall find that the first has diminished neither the quantity of oxygen nor of carbonic acid; and that in the second, on the contrary, the quantity of carbonic acid has diminished, while the quantity of free oxygen has increased in the same proportion. Or if we place two similar plants in closed vessels in the sun, the one in a vessel containing no carbonic acid, and the other in air which contains a known quantity of it, we shall

find that the air in the first vessel has undergone no change, while that in the second will indicate an increase of oxygen proportioned to the quantity of carbonic acid which has disappeared; and, if the experiment is conducted with sufficient care, we shall discover that the plant in question has gained a proportionable quantity of carbon. Therefore, the carbonic acid which has disappeared has given its oxygen to the air and its carbon to the plant, and this has been produced solely by the action of solar light."

It is a very curious circumstance, however, that although the direct solar rays are requisite to produce a decomposition of carbonic acid in plants under experiment, yet that the most feeble diffused light of day is sufficient to produce the result more or less in a natural state. Thus we find that plants growing in wells, in rooms partially darkened, in deep forests, on the north side of high walls, and on which not a single ray of sunlight ever fell, become green, and often perform all their functions, without much apparent inconvenience. Yet De Candolle found the purest daylight, the brightest lamp-light, insufficient to bring about the decomposition of carbonic acid in an obvious manner.

It is not any kind of water in which oxygen will be evolved in the sunshine; neither boiled water, nor distilled water, nor that in which nitrogen, hydrogen, or even oxygen, has been dissolved, will produce the result. But if a small quantity of carbonic acid is dissolved in the water, the green parts, stimulated by the sun, disengage oxygen. Various ingenious means have been contrived to prove this fact, and to show that the quantity of oxygen given out is proportioned to the quantity of carbonic acid decomposed. One of the prettiest experiments is the following, by De Candolle:—He placed in the same cistern two inverted glasses, of which one (A), as well as the cistern itself, was filled with distilled water, and had a plant of Water Mint floating in it; the other glass (B) was filled with carbonic acid. The water of the cistern was protected from the action of the atmosphere by a deep layer of oil. The apparatus was exposed to the sun. The carbonic acid in the glass B diminished daily, as was obvious from the water rising in it; and at the same time there rose to the top of the glass A

a quantity of oxygen, sensibly equal to the quantity of carbonic acid absorbed. During the twelve days that the experiment was continued, the Mint plant remained in good health; while, on the contrary, a similar plant, placed under a glass, filled with distilled water only, had disengaged no oxygen, and exhibited manifest signs of decomposition. The same experiment having been tried, only employing oxygen in the place of carbonic acid, no gas was disengaged in the glass that contained the Mint plant.

This is sufficient to show that the green parts of plants exposed to the sun decompose carbonic acid. By others, not less ingenious, it has been ascertained that the carbon which is the result becomes fixed in the plant itself. It has been found that Periwinkles, growing where carbonic acid had access to them, gained carbon; while similar plants, in a situation cut off from the access of carbonic acid, not only gained no carbon, but lost a part of what they previously possessed.

If the green parts of plants are placed in the dark, in a receiver full of atmospheric air, we find that the quantity of oxygen is perceptibly diminished. From this, and many other considerations, we are forced to conclude that oxygen is absorbed by plants at night. This gas does not, however, remain in the system of a plant in an elastic state, for neither the air-pump nor heat will separate it; but it appears to incorporate itself with the tissue, since solar light readily disengages it. The inference therefore is, that it is absorbed at night, and combines with the carbon already existing, forming carbonic acid, and that the latter is decomposed by the sun, as has before been shown.

It has been ascertained from other experiments, that a small quantity of carbonic acid is perpetually evolved by leaves both day and night. Some observations by Burnett, upon this subject, are detailed in the *Journal of the Royal Institution*, and have led their ingenious author to the opinion, that under the name of respiration two distinct phenomena are confounded; and that while respiration, properly so called, which consists in the extrication of carbonic acid, is incessantly in action, digestion, which is indicated by the decomposition of

carbonic acid and extrication of oxygen, takes place exclusively in daylight. "Hence," he says, "are we not justified in concluding that the production of oxygen, and its converse, the formation of carbonic acid, are the unvarying results of two different functions; viz. this of respiration, that of digestion; and that both are vegetative actions dependent upon vitality? To conclude: the formation of carbonic acid is constant both by day and night, during the life of the vegetable; it is equally carried on whether in sickness or in health; it is essential to its existence for the sustentation of its irritability; for, if deprived of oxygen, and confined in carbonic acid gas, plants, like animals, quickly die. This function, which is performed chiefly by the leaves and petals, though also in a less degree by the stems and roots, like the respiration of animals, is attended with, and marked by, the conversion of oxygen into carbonic acid; it is the respiration of plants.

"Again: vegetables, at certain times and under certain circumstances, decompose carbonic acid, and renovate the atmosphere by the restoration of its oxygen; but this occasional restoration is dependent, not upon the respiratory, but the digestive system: it in part arises from the decomposition of water, but chiefly from the decomposition of carbonic acid, absorbed either in the form of gas or in combination with water, either by the roots or leaves, or both; and here again the analogy holds good between the functions of respiration and digestion in animals and plants, for to both is carbonic acid deleterious when breathed, and to both is it invigorating to the digestive organs." (*Journal of Royal Institution*, new series, vol. i. p. 99.) This is not, however, conformable to the experiments of Mr. Haseldine Pepys, to be mentioned in a future page.

As the decomposition of carbonic acid gas is thus evidently an important part of the act of digestion, it might be supposed that to supply a plant with a greater abundance of carbonic acid than the atmosphere will usually yield would be attended with beneficial consequences. To ascertain this point several experiments have been instituted; the most important of which are those of Saussure, who found that, *in the sun*, an

atmosphere of pure carbonic acid gas, or even air containing as much as sixty per cent. was destructive of vegetable life; that fifty per cent. was highly prejudicial; and that the doses became gradually less prejudicial as they were diminished. From eight to nine per cent. of carbonic acid gas was found more favourable to growth than common air. This, however, was only in the sun: any addition, however small, to the quantity of carbonic acid naturally found in the air, was prejudicial to plants placed in the shade.

The digestion of a plant seems, then, to consist to a great extent in a successive diurnal decomposition and recomposition of carbonic acid. By night it vitiates the atmosphere by robbing it of its oxygen, by day it purifies it by restoring it. It is a curious question whether, by this alternation of phenomena, the vegetable kingdom actually leaves the atmosphere in its original state, or whether it purifies it permanently, giving it more oxygen than it deprives it of. Considering the great loss of oxygen produced either by the respiration of animals, or by its combination with various mineral matters, or by other means, it is to be supposed that the atmosphere would in time become so far deprived of its oxygen as to be unfit for the maintenance of animal life, if it were not for some active compensating power. This appears to reside in the vegetable kingdom; for Professor Daubeny, of Oxford, has ascertained, by experiments communicated to the British Association, that plants undoubtedly exercise a purifying influence on the atmosphere. In a letter to myself he expresses himself thus:—

"As the observations of Ellis left it in some doubt whether the balance was in favour of the purifying or the deteriorating influence upon the air which is exercised by plants during different portions of the day and night, I conducted my experiments in such a manner that a plant might be inclosed in a jar for several successive days and nights, whilst the quality of the air was examined at least two or three times a day, and fresh carbonic acid admitted as required. A register being kept of the proportion of oxygen each time the air was examined, as well as of the quantity of carbonic acid introduced, it was invariably found that, so long as the plant

continued healthy, the oxygen went on *increasing*, the diminution by night being more than counterbalanced by the gain during the day. This continued until signs of unhealthiness appeared in the confined plant, when, of course, the oxygen began to decrease.

"In a perfectly healthy and natural state, it is probable that the purifying influence of a plant is much greater; for when I introduced successively different plants into the same air, at intervals of only a few hours, the amount of oxygen was much more rapidly increased,—in one instance to more than 40 per cent. of the whole, instead of 20, as in the air we breathe."

Thus, the vegetable kingdom may be considered as a special provision of nature, to consume that which would render the world uninhabitable by man, and to have been so beautifully contrived that its existence depends upon its perpetual abstraction of that, without the removal of which our own existence could not be maintained.

But, although the experiments of phytochemists have led to these general conclusions, it is not at all probable that the digestion of plants is limited to the decomposition and recomposition of carbonic acid. It has already (page 261) been stated that Messrs. Edwards and Colin have proved that water is decomposed in the act of germination, the *hydrogen* being fixed and the oxygen set free; and there can be little doubt that this phenomenon occurs in plants during other periods, perhaps all periods, of their vigorous growth.

Théodore de Saussure found that germinating seeds absorb *nitrogen*. It has been shown by M. Boussingault, that plants abstract from the air a quantity of this gas, which they fix in their tissue. But under what circumstances, or in what state, this element is fixed in plants is unknown at present. Nitrogen may enter directly into plants if their green parts are fit to fix it; it may pass into plants with the aerated water absorbed by the roots; and it may be possible, says M. Boussingault, that, as some suppose, there exist in the atmosphere very small quantities of ammoniacal vapour,

a supposition since verified by Professor Liebig and others. M. Payen has also ascertained that this gas exists in abundance in plants. He finds it most plentiful in nascent organs, in those in the act of first development, and in cambium; but he meets with it in wood generally. If a large quantity of water is passed through a stick of elder wood recently cut, the wood loses all its azotised matter, which is carried off by the water: this and some other observations satisfy him that wood generally contains a fluid charged with nitrogen; and he thence infers that the substances employed to prevent the decomposition of wood do so by acting upon the azotised matter, which they coagulate and render insoluble in water. (*Comptes rendus,* vi. 102. 132., vii. 889.) The cause of the importance of nitrogen to vegetation having been so long overlooked, is explained by the committee which reported to the Institute upon M. Boussingault's observations. (*Comptes rendus,* vi. 130.)—"One has been involuntarily led to suppose that nitrogen takes no part in the phenomena of vegetation, because we know that in its gaseous state it enters into combination with much difficulty. Sufficient attention has not been paid to the facility with which, on the other hand, dissolved nitrogen forms energetic combinations, nor to the pasturage of cattle on high mountains, whence there is annually abstracted, in the form of fat or milk, so much nitrogen, which nevertheless can scarcely reach such situations except by the atmosphere."

CHAPTER XIV.

OF SECRETIONS.

THE result of the foregoing phenomena is, the formation of numerous principles peculiar to the vegetable kingdom, and the deposit of others which have been introduced into the system of plants in the current of the sap. Thus are produced, on the one hand, the sugar of the Cane, and of various fruits; the starch of Corn, Potatoes, and other farinaceous plants; the gum of the Cherry; the tannin of the Oak; and all those multitudes of azotised, oily, resinous, and other substances, of which the modern chemist has ascertained the existence; and on the other hand, the various mineral matters left as ashes after vegetable bodies have been burnt.

As light* is one of the chief agents by which the decomposition, recomposition, and assimilation of the juices of plants take place; and as it must be obvious that the intensity of the action of vegetable secretions, or their abundance, will depend upon the degree of their elaboration; it would seem that these must be in direct proportion to the mere quantity of light they have been exposed to. The author of the article Botany, in the *Library of Useful Knowledge,* has remarked that "We see in practice that the more plants are exposed to light when growing naturally, the deeper is their green, the more robust their appearance, and the greater the abundance of their odours or resins; and we know that all the products to which these appearances are owing are highly carbonised. On the contrary, the less a plant is exposed to sunlight, the paler are its colours, the laxer its tissue, the fainter its smell,

* For some highly interesting experiments upon the effect of light passing through coloured media, in determining the appearance of the lower plants and animals, see Morren's *Essais sur l' Hétérogénie dominante;* Liège, 1838.

and the less its flavour. Hence it is that the most odoriferous herbs are found in greatest perfection in places or countries in which the sunlight is the strongest; as sweet herbs in Barbary and Palestine, Tobacco in Persia, and Hemp in the bright plains of extra-tropical Asia. The Peach, the Vine, and the Melon, also, nowhere acquire such a flavour as under the brilliant sun of Cashmere, Persia, Italy, and Spain.

"This is not, however, a mere question of luxury, as odour or flavour may be considered. The fixing of carbon by the action of light contributes in an eminent degree to the quality of timber, a point of no small importance to all countries.

"It is in a great degree to the carbon incorporated with the tissue, either in its own proper form, or as resinous or astringent matter, that the different quality in the timber of the same species of tree is principally owing. Isolated Oak trees, fully exposed to the influence of light, form a tougher and a more durable timber than the same species growing in dense forests; in the former case its tissue is solidified by the greater quantity of carbon fixed in the system during its growth. Thus we have every reason to believe that the brittle Wainscot Oak of the Black Forest is produced by the very same species as produces the tough and solid naval timber of Great Britain. Starch, again, in which carbon forms so large a proportion, and which, in the Potato, the Cassava, Corn, and other plants, ministers so largely to the nutriment of man, depends for its abundance essentially upon the presence of light. For this reason, Potatoes grown in darkness are, as we say, watery, in consequence of no starch being developed in them; and the quantity of nutritious or amylaceous matter they contain is in direct proportion to the quantity of light to which they are exposed. For this reason, when orchard ground is under-cropped with Potatoes, the quality of their tubers is never good; because the quantity of light intercepted by the leaves and branches of the orchard trees, prevents the formation of carbon by the action of the sun's rays upon the carbonic acid of the Potato plant. Mr. Knight has turned his knowledge of this fact to great account, in his application of the principles of vegetable physiology to horticultural purposes."

That the intensity of light does in fact vary most materially in different climates, is a matter of inference from the difference of temperature. Sir John Herschel, in a communication to the *Athenæum* newspaper of April 25, 1835, gives the force of sunshine at the Cape of Good Hope as 48·75°, while ordinary good sunshine in England is only from 25° to 30°.

It is not, however, light alone which is capable of determining the quality of vegetable secretions; it is light in connection with perspiration, and abundant food. The second is promoted, and the latter augmented by continual currents of air, which, rapidly passing over vegetable surfaces, abstract water, and convey a ceaseless supply of carbonic acid for absorption. Hence it is that plants in hothouses, although exposed to the brightest light, are rarely comparable for health or for the concentration of their secretions to the same species in the open air.

Temperature must also exercise a most energetic effect upon those chemicovital actions which end in the production of vegetable secretions. We are assured by Dr. Christison that the Œnanthe crocata, one of the most venomous of our wild herbs, as it grows wild in the neighbourhood of Edinburgh, is destitute of narcotic properties at all seasons. "The juice of a whole pound of the tubers, the part which has proved so deadly elsewhere, had no effect when secured in the stomach of a small dog, either at the end of October, when the tubers are plump and perfect, but the plant not above ground, or in the month of June, when it was coming into flower; and an alcoholic extract of the leaves, and that prepared from the ripe fruit, had no effect whatever when introduced into the cellular tissue of the rabbit under the same conditions in which the common hemlock acts so energetically. By a comparative experiment he ascertained that tubers collected near Liverpool, acted with considerable violence on the dog." The same singular fact has been observed by Dr. Christison in the Cicuta virosa, which he describes as being innocuous in Scotland, or nearly so. In these cases it seems difficult to explain the want of active properties, except upon the supposition that the temperature of Scotland is too low

for eliciting the chemical action which ends in producing poison, although it may be high enough for mere vegetation. The inferior quality of European Rhubarb, Hemp, and Tobacco is perhaps referable to the same circumstance.

The quality of secretions is not, however, always dependent upon the action of external agents: but is in some cases connected with vital processes too obscure for the explanation of the physiologist. Dr. Christison has found by experiment that, although the Midsummer leaves of Conium are very active, yet that they are eminently energetic in the young plant, both at the beginning of November and in the month of March, before vegetation starts on the approach of genial weather. The fruit, in like manner, is most active when full grown, but still green and juicy; it then yields much more of the active principle Conia than afterwards, when it is ripe and dry. Possibly this may have some connection with the chemical composition of Conia, which being an azotised principle may be expected to disappear with the nitrogen necessary to its constitution, and which is most abundant in the youngest parts. In like manner Tannin seems to be more abundant in young plants than in old, in spring than in autumn, although, not being an azotised product, the conjecture as to Conia will not apply to it.

In many cases a secondary action takes place in plants, dependent upon mere vital force, and unconnected with any direct action of light, air, or temperature. There can be no doubt that the process of "ripening" in the Potato, which consists in a gradual change of its gummy matter into starch, is of this nature. This phenomenon occurs in the tubers, is naturally produced in darkness, and in a low temperature, and is independent of light. It goes on till late in the autumn, and does not cease till the temperature becomes too low to favour chemical alterations. Schleiden has, however, objected to this statement. "I must here advert to a mistake which has often been repeated, and which if continued will throw Vegetable Physiology into confusion. De Candolle thought he had shown that 100 lbs. of Potatoes gave in August 10 lbs. of starch, in September 14½ lbs., in October 14¾ lbs., in November 17 lbs., in April 13¾ lbs., in May again 10 lbs.

Hence it was inferred that the quantity of starch in the Potato decreases in these periods; an erroneous conclusion, but one which of late has often been drawn. Yet it is obvious that such per centage determinations only give the relative, and not the absolute, quantity for either a plant or part of a plant. De Candolle's statement, even if correct, shows nothing more than that the proportion of the weight of starch to the whole weight of a Potato is successively that of 10, $14\frac{1}{2}$, 17, &c., to 100, but whether this altered proportion depends on the change of the contained starch or the diminution of other matter, is nowhere stated. It is far more likely that in this the starch is neither formed nor destroyed, but that the water contained in the Potato is lost by evaporation, and is regained by absorption when the plants again begin to grow." But if he thought De Candolle wrong, Professor Schleiden should have produced some counter proof; instead of which we have a mere opinion, very decidedly given, but wholly unsupported by evidence, and contrary to every one's experience.

In the Beet-root the part most rich in sugar is that near the lower end, where the earth prevents the light from penetrating; if the above-ground portion is earthed up, we are assured by M. Gaudichaud that the quantity of sugar then is increased. In like manner in the Sugar cane it appears that the lowest joints of the stem, most remote from the leaves, are the richest in sugar, and *vice versâ*. Whence M. Gaudichaud concludes that sugar is not secreted in such plants by their leaves. The facts just stated do not, however, prove any such thing; they only show that a secondary action takes place in certain plants, in places far removed from leaves, and that this action is facilitated by (or connected with) the absence of light.* But the matter out of which the sugar was obtained all derived its origin, in *the first*

* Upon these phenomena M. Gaudichaud makes the following just remark: —"Il y a dans la nature une physiologie, et une chimie physiologique ou chimie naturelle, dont les phénomènes s'accomplissent sous l'action de la vie et pour la vie elle-même; chimie entièrement distincte, à nos yeux, de celle qui traite et n'a encore pu traiter que des corps inorganiques et des corps organisés mourants, ou entièrement privés de vie, qui tue et ne saurait rien animer, et que bien mal à propos, selon nous, on décore du titre de physiologie.

instance, from the leaves, when it was produced under the influence of light, air, and heat.

The principal part of the secretions of plants is deposited in some permanent station in their system; as in the roots of perennials, and the bark and heartwood of trees and shrubs. It appears, however, that they have, besides this, the power of getting rid of superfluous or deleterious matter in a material form. In the Limnocharis Plumieri there is a large pore terminating the veins of the apex of the leaf, from which water is constantly distilled. The pitchers of Nepenthes, which are only a particular kind of leaves, secrete water enough to fill half their cavity. But, besides this more subtle fluid, secretions of a grosser quality take place in plants. The honey dew, which is so often attributed to insects, is one instance of the perspiration of a viscid saccharine substance; the manna of the Ash is another; and the gum ladanum that exudes from the Cistus ladaniferus is a third instance of this kind of perspiration.

Some of these phenomena deserve to be more particularly noticed. Dr. L. F. Gærtner has described them in Calla æthiopica. He states that the vessels of the leaf are not continued in this plant to the end of the awl-shaped prolongation at the apex of the leaf, but that the secretion takes place at the extreme end of this prolongation, for the length of 1 to 1·5 millimetres, but is scarcely visible until the fluid has collected into a drop. After the death of the point, the margin of the apex of the leaf assumes the function. The special organs of exudation seem to be the long pores of the epidermis; as is also the absorption of the secreted fluid, which is sometimes observed. Light has no perceptible influence on the dropping from the leaves. Warmth alone has no special action, though it has when it is combined with immersion in water. The excretion was feeblest in a morning; increased towards noon; was most copious in the afternoon from two to five P.M., and declined again during the night; but this periodicity is not accurately determined. There can be no doubt that the dropping arises from an excess of fluid beyond that which is requisite for the nourishment of the plant.

The same author observed a similar phenomenon in the leaves of Canna angustifolia, indica, and latifolia. The secretion of watery fluid takes place in these plants, not from the point of the leaves as in Calla, but from the points of the parallel ribs, which terminate at the margin of the leaf; and generally in greater abundance from those nearest the apex of the leaf. From these points of the principal veins, where they lose themselves in a delicate network, towards evening and at night there exudes imperceptibly a clear watery fluid, which collects in drops and patches on the upper and on the under surface of the lamina, occasionally running from it as copiously as from the point of the Calla æthiopica. Temperature seems to have some connection with this excretion, which is rather promoted by the growth of the leaves, but ceases when the plant puts forth flowers. Observations of a similar kind have been published by Rainer Graf, (*Flora*, 1840, p. 432.) In the Impatiens nolitangere he observed drops of fluid on the cotyledons, and in the first leaves at the edge whilst still folded together in the bud. As soon as the leaves attain their full size, the drops appear on the crenatures, at the point of each sepal, until the capsule begins to swell, at the point of the bracts, and also on the flowers. They appear there at the middle tooth of the upper arched petal, and at the point of the lower valve-like calcarate petal. The drops are largest on the cotyledons; those on the leaves follow next; and there they are always larger at the points of the ribs than at the points of the secondary nerves. The drops, which in other respects consist of perfectly tasteless and scentless water, usually appear within ten or twenty minutes after rain or watering the plant. It appears that the vessels which are situated in the ribs of the leaves carry the sap rapidly from one place to another, conducting it finally to those points where it is necessary for the nourishment of the plant, and throwing it off them when in excess, or when carried thither faster than it can be absorbed.

In these cases it can scarcely be said that special organs are formed for carrying on the office of secretion. In many plants, however, glands are evidently provided for such a

purpose. They have been examined by M. Trinchinetti, who describes them to be small bodies, sometimes conical, sometimes globular, either naked or hairy, and sometimes defended by a spine. He names them *periphylls* because they chiefly occur near the periphery, or circumference of a leaf. They vary, however, greatly in appearance, as has been shown in the first volume when speaking of glands. One of the most common forms is that which occurs among the phyllodineous Acacias. Unger states that in Acacia longifolia, at the base of the lamina or of the phyllode, and on its upper edge, "a small impression is remarked in the form of a point, which is the orifice of the excretory canal of a cavity existing in the substance of the organ. This cavity is not hollowed in the ordinary parenchym, but is surrounded entirely by peculiar cells with small and thin walls, the whole constituting a sort of glandular apparatus, shaped like a kidney-bean, bulky, and almost as large as a third of the phyllode. It is surrounded by several vascular bundles, and has direct relations with four of them. The cells which form the gland contain no solid matter; but those which surround this apparatus contain granules of starch, which become more numerous and larger in proportion to their distance. The liquid which fills them is turbid, which shows its state of concentration. On examining it with the aid of some re-agents, Unger found that it contains, besides sugar, a second substance, which is gum or vegetable mucilage. From this and other observations M. Unger infers that the nectariferous glands of leaves exhibit in their essential structure a great analogy with one another and that the production of sugar is effected in all in the same manner.

In many plants, however, the secretions are effected without the assistance of any apparent glandular apparatus. According to Morren the fat or fixed oils are merely formed in cells, while the volatile oils are secreted in glands formed for the express purpose. This is, however, denied by Link, who asserts that in general volatile oil is deposited in the common cells of the plant, where it appears more or less plainly in the form of small oily drops among the sap, or even in large masses. This is almost always the case in the petals, and it is very rare that the oil is secreted in internal glands.

CHAPTER XV.

OF RESPIRATION.

THE general facts belonging to vegetable respiration have been mentioned in the Chapter on Digestion. There are, however, certain phenomena connected with this process which may be most conveniently treated of separately.

Carbonic Acid. It has been already stated that the experiments of Burnett led him to conclude that a small quantity of carbonic acid is continually evolved by plants. This seems to be proved by the carbonate of lime which gradually forms upon the surface of fresh leaves when plunged in lime-water; and Liebig regards it as a phenomenon necessarily attendant upon the function of perspiration; for he says that in the escape of water from the surface of plants, carbonic acid dissolved in it cannot do otherwise than accompany it. It is, however, to be observed that the very careful and extensive series of experiments carried on by Mr. Haseldine Pepys, and recorded in the *Philosophical Transactions* for 1843, do not confirm this opinion. This gentleman selected for experiment specimens of plants which had been previously habituated to respire constantly under an inclosure of glass; and employed the apparatus which he had formerly used in experimenting on the combustion of the diamond, consisting of two mercurial gasometers, with the addition of two hemispheres of glass closely joined together, so as to form an air-tight globular receptacle for the plant subjected to experiment. The general conclusions he deduced from his numerous experiments, conducted during several years, were, first, that in leaves which are in a state of vigorous health, vegetation is always operating to restore the surrounding atmospheric air to its natural condition, by the absorption of carbonic acid and the disengagement of oxygen: that

this action is promoted by the influence of light, but that it continues to be exerted, although more slowly, even in the dark. Secondly, that carbonic acid is never disengaged during the healthy condition of the leaf. Thirdly, that the fluid so abundantly exhaled by plants in their vegetation is pure water, and contains no trace of carbonic acid. Fourthly, that the first portions of carbonic acid gas contained in an artificial atmosphere, are taken up with more avidity by plants than the remaining portions; as if their appetite for that pabulum had diminished by satiety. In like manner Dr. D. P. Gardner speaks in the most positive manner to the absence of free carbonic acid in the interior of the green parts of plants at from 11—12 A.M., "during vigorous existence in the presence of bright diffused lights in summer." In other cases, however, he found 2·4 per cent.; and Calvert and Ferrand always found minute quantities of it at night in the hollow stems of Phytolacca decandra.

Although *nitrogen* is, as has already been shown, an important and constant element in vegetation, when dissolved or obtained by separation from the atmosphere, yet in a pure gaseous state it seems incapable of affording any support to the development of plants, as proved by Théodore de Saussure, who found that, five days after immersion in pure nitrogen, the buds of poplars and willows were in a state of decay. But he inclined to ascribe the apparent incapability of leafy plants to absorb nitrogen to the artificial conditions under which the experiments were conducted. And this is probable, considering the nature of modern discoveries with respect to the action of nitrogen in vegetation.

There can be no doubt that nitrogen is a product of vegetable respiration. Mr. Rigg's experiments, already mentioned (p. 274), are conclusive upon that point, and are confirmed by those of Dr. D. P. Gardner (*Phil. Mag.* xxviii. 430). "By overlooking," he observes, "the laws of penetration, De Candolle, Saussure, Ingenhouz, and Plenck are thrown into contradictory positions in their experiments on the action of the green parts of plants on artificial atmospheres. Thus De Candolle (*Phys. Veg.* t. i. p. 133), 'Les parties vertes laissent moins de gas oxigène dans le gas azote; elles ne

paraissent, contre l'assertion d'Ingenhouz, absorber ni l'un ni l'autre. Il parait aussi certain, malgré l'assertion de Plenck, qu'elles n'exhalent point de gas azote, sauf dans quelques cas, par les corolles.' In the summer of 1844 I tested this question by placing some specimens of the Conferva mucosa in pump-water and in carbonated water, and allowing them to act for several days on the same water, removing each day the gas generated during light; the plants were therefore subjected in their natural medium to different mixtures of gases dissolved in the fluid. The result was, that the plants in pump-water gave in six hours a gas consisting of O73, N27 per cent.; in twenty-four hours, O53, N47 per cent.; in forty-eight hours, O18·6, N81·4 per cent. In carbonated water, in six hours, O68 per cent.; in twenty-four hours, O63 per cent.; in forty-eight hours, O12, N88 per cent.; in seventy-two hours, O3·5, N96·5 per cent. And these plants continued healthy, and acted as before when fresh water was added."

Pure *hydrogen* seems to act unequally upon vegetation. Saussure found that a plant of Lythrum Salicaria, after five weeks, had caused no alteration in a known volume of hydrogen by which it was surrounded, and had not itself experienced any apparent effect. Sir Humphry Davy, however, states that some plants will grow in an atmosphere of hydrogen, while others quickly perish under such treatment.

According to Dumas we possess decided proofs that certain fungi naturally give off hydrogen. MM. Edwards and Colin have shown that hydrogen is also disengaged by the stems of Polygonum tinctorium when under water. It has been demonstrated by M. Payen by analysing the woody parts of plants, that the hydrogen in these parts is always in slight excess with respect to the oxygen.

We must add to this the direct experiments made by M. Boussingault on the development of Peas, of Clover, and of Wheat. These experiments gave the following results:—

WHEAT.

	Seeds.	After three months' vegetation.	100 parts of seed have fixed
Carbon	46·6	88·0	41·4 carbon.
Hydrogen	5·8	10·0	0·0 nitrogen.
Nitrogen	3·5	3·7	41·8 water.
Oxygen	44·1	81·0	0·0 hydrogen.
	100·0	183·2	183·2

CLOVER.

	Seeds.	After three months' vegetation.	100 parts of seed have fixed
Carbon	50·8	131·3	80·5 carbon.
Hydrogen	6·0	17·1	2·6 nitrogen.
Nitrogen	7·2	9·8	72·8 water.
Oxygen	36·0	100·7	3·0 hydrogen.
	100·0	258·9	258·9

The Wheat fixed a great deal of carbon and water, but no hydrogen; whilst the Clover fixed carbon, nitrogen, hydrogen and water. (*Dumas Traité de Chimie appliquée aux Arts*, tom. viii. p. 441.)

Drs. Turner and Christison found that so small a quantity as $\frac{1}{10000}$ of *sulphurous acid gas*, a proportion so minute as to be imperceptible to the smell, was sufficient to destroy the life of leaves in forty-eight hours. The same observers state, in their paper in *Brewster's Journal* for January, 1828, the effects of other gases upon plants. *Hydrochloric*, or *muriatic acid gas* was found to produce effects not inferior,—nay, even superior,—to those of the sulphurous acid. It was found that so small a quantity as a fifth of an inch, although diluted with 10,000 parts of air, destroyed the whole vegetation of a plant of considerable size in less than two days. "Nay, we afterwards found that a tenth part of a cubic inch, in 20,000 volumes of air, had nearly the same effects. In twenty-four hours the leaves of a laburnum were all curled in on the

edges, dry and discoloured; and, though it was then removed into the air, they gradually shrivelled and died. Like the sulphurous acid, the hydrochloric acid gas acts thus injuriously in a proportion which is not perceptible to the smell. Even a thousandth part of hydrochloric acid gas is not distinctly perceptible; a ten-thousandth made no impression on the nostrils whatever, although great care was taken to dry thoroughly the vessels used in making the mixtures.

This, however, by no means agrees with the observations of others, which go to show that although muriatic acid in excess is, like all other acrid fluids, destructive of vegetation, yet in minute doses it may be beneficial. This was shown some years since by experiments tried in the Garden of the Horticultural Society. Mr. Fortune found that when plants were placed in a confined situation, and exposed to the fumes of weak muriatic acid, so far were they from suffering in consequence, that they grew with augmented vigour; and when half killed by exposure to deleterious influences, they rapidly recovered by being brought in contact with this vapour.

Mr. Solly has found that not only is the vapour of muriatic acid inoffensive in moderate quantity, but that no action of an unfavourable kind is produced upon plants even by large quantities applied to the roots. Upon this singular fact we must quote his words:—

"Two perfectly similar plants of the Hydrangea were taken and placed under the same general conditions with respect to light, air, &c., and watered with dilute solutions, the one of carbonate of soda, the other of muriatic acid, commencing with very small quantities and gradually increasing the doses. At the beginning of the experiment it was difficult to distinguish the one from the other; they had both the same number of leaves, were nearly of the same size, and alike in colour and general vigour, being both remarkably healthy plants. The solutions taken consisted of one drachm of concentrated muriatic acid, and one drachm of carbonate of soda, each dissolved in fifty drachms of water; of these at first one drachm diluted with two ounces of water was given to each plant daily, but the dose was gradually increased to twelve drachms of each solution, so that in a month the one had

received nearly five drachms of concentrated muriatic acid, and the other plant more than half an ounce of carbonate of soda. Under this mode of treatment both plants continued to thrive and flourish, and the blossoms were large and perfect, those formed by the plant treated with muriatic acid being rather the more forward of the two: they were, however, both of the same colour, nearly blue, although it was believed that had they been left untouched, the blossoms would have been pink. It is evident that the acid would have a tendency to render certain matters in the soil more soluble than others, whilst the carbonate of soda would have an opposite effect; the acid would render lime, magnesia, bases, and metallic oxides more soluble, whilst the carbonate of soda would facilitate the solution of silica, acids, and organic substances in the soil.

"During the progress of these experiments, two facts worthy of record were observed: the one was, that some plants are able to absorb a large quantity of muriatic acid; and secondly, that great influence is exerted on the rate of evaporation of the leaves, by the substances absorbed from the soil. I was surprised to find how very large a quantity of this acid the plants were able to take up, and that so far from producing bad effects they flourish under its influence. The greatest quantity which I gave was from one-fifth to one-fourth of a drachm of strong acid to the plant per day—of course dissolved in a larger quantity of water, but still so strong as to be about as sour to the taste as common vinegar."

We cannot but regard this as a highly curious result. It is, however, the more remarkable as being connected with a fact for which there seems no explanation. When plants are fed with muriatic acid, their rate of perspiration is checked. "Thus," says Mr. Solly, "when two Hydrangeas, the one watered with acid, the other with carbonate of soda, were placed under the same circumstances, and watered with three ounces of water each, the one watered with the alkaline solution began to fade, and seemed parched up by heat in the middle of the day; whilst the other remained crisp and fresh-looking. Subsequently it received five ounces of water daily, but even

this did not seem sufficient, and seven ounces of water were found necessary to keep it in a condition similar to the other, which was watered with three ounces, but under the influence of the muriatic acid. It might at first be supposed that this effect was principally due to the action of the carbonate of soda; but by comparing the plants with others similarly situated, there appeared little doubt that the rate of evaporation was diminished in that under the influence of the acid, and not that it was increased in the one watered with the alkaline solution."

Chlorine may be expected to have the effects of hydrochloric acid gas; and so indeed it has, but they appear to be developed more slowly. Two cubic inches, in two hundred parts of air, did not begin to affect a mignonette plant for three hours; half a cubic inch, in a thousand parts of air, did not injure another in twenty-four hours: but when the plants did become affected, the same drooping, bleaching, and desiccation were observed. (*Turner and Christison.*)

Nitrous acid gas is probably as deleterious as the sulphurous and hydrochloric acid gases. In the proportion of a hundred and eightieth, it attacked the leaves of a mignonette plant in ten minutes; and half a cubic inch, in 700 volumes of air, caused a yellowish green discoloration in an hour, and drooping and withering in the course of twenty-four hours. The leaves were not acid on the surface. (*Turner and Christison.*)

The effects of *sulphuretted hydrogen* are quite different from those of the acid gases. The latter attack the leaves at the tips first, and gradually extend their operation towards the leafstalks; when in considerable proportion, their effects began in a few minutes; and if the quantity was not great, the parts not attacked generally survived, if the plants were removed into the air. The sulphuretted hydrogen acts differently; two cubic inches, in 230 times their volume of air, had no effect in twenty-four hours. Four inches and a half, in eighty volumes of air, caused no injury in twelve hours; but, in twenty-four hours, several of the leaves, without being

injured in colour, were hanging down perpendicularly from the leafstalks, and quite flaccid; and, though the plant was then removed into the open air, the stem itself soon began also to droop and bend, and the whole plant speedily fell over and died. When the effects of a large quantity, such as six inches in sixty times their volume, were carefully watched, it was remarked that the drooping began in ten hours, at once from the leafstalks; and the leaves themselves, except that they were flaccid, did not look unhealthy. Not one plant recovered, any of whose leaves had drooped before it was removed into the air. (*Turner and Christison.*)

The general opinion respecting the action of this gas has been unfavourable. It evidently acts on plants as a venomous vapour, says M. De Candolle (*Phys.* 1363); it destroys plants when mixed with the air in small doses, and is chiefly inhaled at night, adds the same author in another place (p. 1372), judging from some experiments of the Genevese chemist Macaire. Liebig broadly states that one of the chemical forms in which this agent exists is a deadly poison; and acting, it may be presumed, upon such assertions, the proprietors of gas-works have been exposed to actions from their neighbours to recover compensation for some supposed injury done to their gardens. One would imagine that statements in which great authorities thus concur *must* be well founded. Mr. Solly's experiments, however, by no means confirm them. On the contrary, it would seem that sulphuretted hydrogen gas acts decidedly in a beneficial manner. He says—"I made use of the hydrosulphuret of ammonia, the very compound described by Liebig as being a 'deadly poison;' but in place of killing plants, I found that in small quantity it produced decidedly beneficial effects; in some cases when it was applied to plants, in an unhealthy state from the action of other substances, it had the effect of invigorating them, and of restoring their leaves to a healthy, green, and crisp condition. The plants with which these effects were best observed were the garden Lettuce and the common Windsor Bean. The solution of the hydrosulphuret of ammonia employed was prepared by mixing a saturated solution of the compound with fifty times its bulk of water: such a

solution had a most nauseous, disgusting smell, and contained of course a large quantity of sulphuretted hydrogen. The plants under experiment were selected from many, and were of the same age and size, and as far as possible of the same healthy state of growth. Some were watered with common water, others with a dilute solution of hydrosulphuret of ammonia. At first only a few drops of the solution were given; but finding that this produced little or no effect, the dose was increased, and as much as half an ounce a day, and sometimes even more, was given to each plant. It was found that those thus treated became stronger and sturdier; their leaves were of a bright deep green; the space between the nodes, or the distance from leaf to leaf, was shorter, and the stems were stronger, and the whole plant more flourishing than those watered in the ordinary way, although all other circumstances were alike, and care was taken to place all under the same condition, by exposing them equally to air and light, and giving them the same quantity of water every day. Plants in a languid state from over-doses of nitrate of potash, or soda, or other saline manures, if not too much injured by their previous treatment, appeared to recover more rapidly when watered with the solution of hydrosulphuret of ammonia than when merely treated with common water. In some of these latter cases a much stronger solution was employed than that already mentioned, containing two drachms of the saturated solution of hydrosulphuret of ammonia in fifty of water, and of this eight drachms were given daily. For some time after thus watering the plants, the earth retained a strong smell of sulphuretted hydrogen, and the water which drained through, when tested by a salt of lead, evidently contained a large quantity of that gas."

This is only what was to be expected from the abundance of this gas in nature, from the rankness of vegetation when it is extricated copiously, as in the vicinity of privies, and from the fact of its being given off incessantly by putrid substances, and that it is most abundant in the most active of all manures. The error that seems to have been committed by the chemists who investigated its action, appears to have arisen from their submitting plants to too large a dose of it.

Carbonic acid, well recognised as the principal subsistence of plants, will kill them in doses not very considerably greater than that proportion which nature provides; and we ourselves should perish under excessive quantities of even the most nutritious of our daily food.

The effects of *ammonia* were precisely similar to those of sulphuretted hydrogen just related, except that after the leaves drooped they became also somewhat shrivelled. The progressive flaccidity of the leaves, the bending of them at their point of junction with the footstalk, and the subsequent bending of the stem, the creeping, as it were, of the languor and exhaustion from leaf to leaf, and then down the stem, were very striking. Two inches of gas, in 230 volumes of air, began to operate in ten hours. A larger quantity and proportion seemed to operate more slowly. (*Turner and Christison.*)

Yet the carbonate of ammonia in moderate doses is one of the most valuable of all manures, and is freely taken up by the leaves of plants, not only without inconvenience, but with visible advantage.

Cyanogen appears allied to the two last gases in property, but is more energetic. Two cubic inches, diluted with 230 times their volume of air, affected a mignonette plant in five hours; half a cubic inch, in 700 volumes of air, affected another in twelve hours; and a third of a cubic inch, in 1700 volumes of air, affected another in twenty-four hours. The leaves drooped from the stem without losing colour; and removal into the air, after the drooping began, did not save the plants. (*Turner and Christison.*)

Carbonic oxide is also probably of the same class, but its power is much inferior. Four cubic inches and a half, diluted with 100 times their volume of air, had no effect in twenty-four hours on a mignonette plant. Twenty-three cubic inches, with five times their volume of air, appeared to have as little effect in the same time; but the plant began to droop when it was removed from the jar, and could not be revived.

Olefiant gas, in the quantity of four cubic inches and a half, and in the proportion of a hundredth part of the air, had no effect whatever in twenty-four hours. (*Turner and Christison.*)

The *protoxide of nitrogen,* or *intoxicating gas,* the last we shall mention, is the least injurious of all those we have tried; indeed it appears hardly to injure vegetation at all. Seventy-two cubic inches were placed with a mignonette plant, in a jar of the capacity of 500 cubic inches, for forty-eight hours; but no perceptible change had taken place at the end of that time. (*Turner and Christison.*)

Göppert has also found that *hydrocyanic acid* in a gaseous state is fatal to vegetation. Numerous experiments upon the action of this and other substances deadly to plants are to be found in this author's dissertation, *De Acidi Hydrocyanici Vi in Plantas:* Vratislav. 1827. It is the custom of gardeners to strew the crushed leaves of the Laurocerasus over the floor of hothouses, in order to kill insects; but they find that any overdose of it destroys their plants as well.

All the foregoing observations apply to plants whose natural colour is green in consequence of the formation of chlorophyll within their tissue. In those species, however, which are called BROWN PARASITES, including FUNGI, the phenomena of respiration are very different. Marcet has shown, from carefully conducted experiments, "that mushrooms, vegetating in atmospheric air, produce on that air very different modifications from those of green plants in analogous situations; in fact, that they vitiate the air promptly, either by absorbing its oxygen to form carbonic acid at the expense of the carbon of the vegetable, or by disengaging carbonic acid formed in various ways. That the modifications which the atmosphere experiences when in contact with growing mushrooms are the same day and night. That if fresh mushrooms are placed in an atmosphere of pure oxygen, a great part of that gas disappears at the end of a few hours. One portion of the oxygen which is absorbed combines with the carbon of the plant to form carbonic acid; whilst another part appears to

be fixed in the vegetable, and to be replaced, at least in part, by nitrogen disengaged by the mushroom. That when fresh mushrooms remain some hours in an atmosphere of nitrogen, they modify very slightly the nature of that gas. The sole effect produced is confined to the disengagement of a small quantity of carbonic acid, and sometimes to the absorption of a very small quantity of nitrogen."

The remarks of Lory upon this subject are, however, the most recent and complete. The following is an extract from his paper in the *Annales des Sciences for Sept.* 1847, p. 159, on the respiration of Broomrapes (Orobanchaceæ.)

The manner in which these plants behave with respect to the air, or with respect to a mixture of air and carbonic acid, is exactly that which might have been expected, considering that there is no chlorophyll.

In every stage of their vegetation, all the parts of these plants, whether they are exposed to solar light, or whether they are in the dark, absorb oxygen and give out carbonic acid in its place.

Experiments have been made by placing these plants, as fresh as possible, in flasks filled with air, or with a known mixture of air and carbonic acid, closed by tightly-fitting corks, and having their necks plunged in water or mercury. In every case, the flask was closed so tightly that no gas could escape by expanding, and no liquid could enter it when the volume of the gas diminished. In these circumstances, no sensible quantity of carbonic acid can be lost by being dissolved, whilst if the mouth of the flask had not been corked, there would have been a considerable loss of this gas, and the result would have been sensibly erroneous.

In more than thirty experiments made during the months of May and June, the temperature and light, the composition of the atmosphere of the flask, the ratio of the volume of the plant to that of the flask, were all varied as much as possible: and lastly, plants were taken at different stages of growth, from the moment when the stem rose above the soil, until the flowering was completely over.

Each experiment lasted about thirty-six hours; the flask was exposed either to diffused light, or to the full rays of the

sun in the afternoon. It is clear that the mean temperature during the experiment could be taken into account in the first case only.

The following are the results to which I have been led:—

1st. The volume of the gas surrounding the plant varies but very little, even when the greater quantity of oxygen is converted into carbonic acid. The irregularities observed, free from the influence of all circumstances foreign to the phenomena of respiration, are sometimes one way, sometimes another, and they are so trifling that they cannot be taken into account where precision is all but impossible. I placed the plants in a closed flask, holding about a litre, and furnished with a bent tube of inconsiderable volume, which I plunged in mercury. On making the necessary corrections, I never found the level vary more than two millimetres, even when the experiment lasted nearly three days, until nearly the whole of the oxygen was converted into carbonic acid. The means of these variations are altogether inappreciable.

2nd. This first result is confirmed by analysis; the nitrogen being supposed constant, the sum of the oxygen and the carbonic acid remains very nearly indeed, constant; there being, however, almost always a small diminution. Independently of any error arising from the solubility of the carbonic acid, this result may be naturally explained by two circumstances; there is always a little nitrogen given off, and a little oxygen absorbed; two causes which act together to produce the difference in question, by keeping the total volume very nearly constant.

In a mixture of air and carbonic acid, the plant behaves in the same way as in air alone; but as is natural, *cæteris paribus*, a smaller quantity of oxygen is destroyed.

3rd. In an atmosphere of pure hydrogen, the plants which are not green, disengage a large proportion of carbonic acid and a little nitrogen. Thus, as it might have been expected, the disengagement of these gases does not correspond, directly, with the absorption of oxygen; they are only, as in the respiration of animals, definite products of the reactions accomplished in the tissues.

4th. The elevation of temperature stimulates the respira-

tion of plants which are not green; as to the solar light it has but a feeble influence on this phenomenon, and it is probable that it only acts by the elevation of temperature which necessarily accompanies exposure to the direct rays of the sun. If some of these plants, certain Orobancheæ, appear to seek the light at their flowering period, it is doubtless because they have need of solar heat to favour the active respiration established in their floral spike.

At a mean temperature of 18° cent. O. Teucrii in full flower, placed in the air, destroys in thirty-six hours more than four times its volume of oxygen, viz. 4·2 cmc. per gramme; which is equivalent to a loss of 2·26 milligrammes of carbon per gramme. After flowering, the phenomenon becomes much less intense; the stems of the same species, of which all the flowers were faded, only gave 2·68 cmc. of carbonic acid per gramme in thirty-five hours.

The flowering part of the stem of O. brachysepala destroys in the same time, *cæteris paribus*, two-thirds as much oxygen as the flowerless part of the same stem. The difference would be still more striking, if the oxygen absorbed by the flowers alone were compared with that consumed by the rest of the plant. But the manner of respiration is not the less the same at all the stages of growth and for all the organs of the plant.

Thus the respiration of Orobancheæ, and of plants which are not green in general, is precisely the inverse of that of green plants, at least during the day. To make this difference more sensible, I subjoin the following experiment:—

I took a piece of Orobanche Teucrii, the flowers of which were not yet expanded, and also a portion of the leafy stem of Teucrium Chamædrys, each specimen weighing 7·5 grains; they were placed in two receivers, the capacity of each being 220 cmc.; these were filled with a mixture of six volumes of air and one volume of carbonic acid, and exposed to the light from nine in the morning till three in the afternoon of the next day, in a place where they received the afternoon sun. At the end of this time the gas, in the jar containing the

Teucrium, did not afford a trace of carbonic acid, whilst that breathed by the Orobanche was found to consist of

Nitrogen	100
Oxygen	9·35
Carbonic acid . .	37·75

whence it is evident that the proportion of carbonic acid increased considerably, in the same quantity by which the oxygen diminished.

Plants then without green organs, are only incessantly yielding to the atmosphere a part of their carbon, with a small proportion of nitrogen and hydrogen. Far from extracting from them the elements of their nutrition, as green plants do, they obtain all their substance from the soil. Hence, doubtless, arises the necessity of their being parasites, as the greater part of them certainly are. As to the doubtful parasites, the Neottia nidus-avis and the Monotropa hypopitys, can we not suppose that they have the power of reorganising for their own use the *immediate* products of the decomposition of the vegetable matters, so abundant in the fresh woody places in which they grow? Would it not be partly the same with true parasites, often developed to so great a degree relatively to the extent of their points of contact with the mother plant, with the Lathræa squamaria for example? For these sort of plants, as well as for Cryptogams alike without green parts, complete parasitism, or this sort of indirect parasitism, is the only method of nutrition."

CHAPTER XVI.

OF THE MOVEMENTS OF FLUIDS.

PLANTS have no circulation of their fluids analogous to that of blood in the higher animals; that is to say, departing and returning incessantly from and to one common point. But that their fluids have a motion may be inferred from their nature; and that it is often of extreme rapidity is proved by the great quantity of water which they perspire; all of which must be replenished by aqueous particles in rapid motion along the tissue from the roots. A young vine leaf in a hot day, perspires so copiously, that if a glass be placed next its under surface it is presently covered with dew, which, in half an hour, runs down in streams. Hales, as has been already seen, computed the perspiration of plants to be seventeen times more than that of the human body. He found a sunflower lose one pound four ounces, and a cabbage one pound three ounces a day, by perspiration. By some contrivances of glass tubes and a mercurial apparatus, he found means to measure the force of suction in particular trees, which will of course be in proportion to the amount of evaporation; and he ascertained that an apple branch 3 feet long would raise a column of mercury $5\frac{3}{4}$ inches in half an hour; a nonpareil branch 2 feet long, with 20 apples on it, 12 inches in 7 minutes; and the root of a growing pear tree 8 inches in 6 minutes. In short, he computed that the force of motion of the sap is sometimes five times greater than that which impels the blood in the crural artery of the horse. This perspiration is regulated in part by the number of the stomates, and in part by the thickness of the epidermis: hence evergreens, in which the stomates are small, and less numerous than in deciduous or

herbaceous plants, and the epidermis thicker and harder, perspire much less than other plants.

M. Biot has succeeded in injecting the red colouring matter of Phytolacca decandra into the flowers of white hyacinths. He learned from a paper by De la Baisse, in the *Recueil des Prix de l'Académie de Bordeaux*, vol. iv., that the juice of this plant is free from all the objections usually found to the red colouring matter used for such experiments, and that he had succeeded in injecting it into all sorts of white flowers, and even green leaves. Biot found, however, that although he did in many cases succeed, yet the practice was attended with peculiar difficulties. Many plants refused the injection altogether, others took it up with rapidity. A few minutes sufficed to vein with a multitude of red lines all the petals of a white monthly rose, while a white musk rose was not affected. He even found that the flowers of the same species resisted the entrance of the colouring matter in an unequal degree.

That a motion of fluids really exists in plants is, therefore, undoubted. It is most rapid in the spring and early summer, and most languid in winter; but never actually suspended, unless under the influence of frost. This has been demonstrated by Biot, who, by means of an apparatus described in the *Institut* Newspaper, succeeded in measuring the power of motion in the sap of plants, in witnessing the phenomena which regulated it, and in determining the causes that brought them about.

"Atmospherical circumstances," he says, "and especially the absence or presence of solar light, exercise a marked influence upon these phenomena; but it is exceedingly difficult to ascertain their exact nature. Nevertheless, among them is one, the effects of which are so constant and undoubted, that they appear susceptible of being defined. This consists in the sudden appearance of frost immediately succeeding mild weather, and lasting for some time. Mild weather either favours or brings about the ascent of the sap; but, if a sudden frost supervenes, it seizes upon the part of the trunk swollen with fluid, and forces the latter to fall back again: should the frost continue and increase in severity,

the earth at the foot of the tree freezes; and, whether at that time the roots are mechanically compressed by it, or whether the duration of the cold causes contraction by a vital action, the roots commence causing a considerable discharge of fluid from the lower part of the apparatus. This goes on night and day, except when the pipes to carry off the sap are frozen. As soon as a thaw comes on and the earth is relaxed, the roots, emptied of their juices, find themselves below their point of saturation; they then emit nothing, but on the contrary absorb the descending juices. I satisfied myself of this not only by my apparatus, but in sawing through the trunk of a large poplar tree, a yard from the ground. The surface of the section of the stump was dry, but that of the trunk itself dripped with water."

The motion of the sap appears to be of two kinds; 1. *general*, and 2. *special:* these must be carefully distinguished. The former is what has been alluded to in the preceding observations; the latter is altogether of a different nature.

Of General Motion.

The course which is taken by the sap, after entering a plant, is the first subject of consideration. The opinion of the old botanists was, that it ascended from the roots, between the bark and the wood: but this has been long disproved by modern investigators, and especially by the experiments of Knight. If a trunk is cut through in the spring, at the time the sap is rising, this fluid will be found to exude more or less from all parts of the surface of the section, except the hardest heartwood, but most copiously from the alburnum. If a branch is cut half through at the same season, it will be found that, while the lower face of the wound bleeds copiously, scarcely any fluid exudes from the upper face; from which, and other facts, it has been fully ascertained that the sap rises through the wood, and chiefly through the alburnum. It is related by Berthellot, that the people of the Canaries tear off the bark of the poisonous Euphorbia canariensis, and suck the limpid sap of the alburnum, which, during its ascent in that part, undergoes but little alteration from its condition when

it enters the roots, and does not partake of the deleterious qualities of the descending sap of the bark. Observations of the same nature have also proved that it descends through the bark and liber. But the sap is also diffused laterally through the cellular tissue, and this with great rapidity; as will be apparent upon placing a branch in a coloured infusion, which will ascend and descend in the manner just stated, and will also disperse itself laterally, in all directions, round the principal channels of its upward and downward route. In trees this lateral transmission takes place chiefly through the medullary rays, which keep up a communication between the bark and the heart-wood, and convey to the latter the secretions which the former may have received from the leaves.

It is, however, by no means in the alburnum or outer layers of wood, that the sap rises exclusively. It certainly passes up any part of the wood which is permeable to fluids, and may even refuse the alburnum. This was proved by an experiment made by me some years ago in charging the wood of a Sycamore tree, in the month of August, with pyrolignite of iron by Boucherie's process. The solution of iron rose freely *near the centre of the wood,* even to the extremities; *but absolutely refused to pass by the alburnum.*

With regard to the vessels through which this universal diffusion of the sap takes place, it has already been stated that its upward course is always through the woody tissue, and partially also through the articulated bothrenchym; and that it passes downwards through the parenchym, and woody tissue of the bark, and through the vessels of the latex. But there can be no reasonable doubt that it is also dispersed through the whole system, by means of some permeable quality of the membranes of the cellular tissue, invisible to our eyes, even aided by the most powerful glasses. It has also been suggested that the sap finds its way upwards, downwards, and laterally, through the intercellular passages. That such a channel of communicating the sap is employed by nature to a certain extent I do not doubt, especially in those plants in which the intercellular passages are very large; but whether this is a universal law, or has only a partial

operation, is unknown, and is not perhaps susceptible of absolute proof.

Upon this subject we have a very interesting paper by Mr. Honninger, of Tubingen (*Botanische Zeitung*, 1843) who has recorded his experiments with the Vine, &c. In summer he found most of the vessels empty; sap, however, was still present, but only in the most internal parts; the prosenchymatous cells of the wood also were still full of sap. By ferrocyanide of potassium and sulphate of iron, he found in the shoots of Lycium barbarum that the most external layers of vessels (tubular tissue) were, for the most part, stained blue, the middle ones empty, and the most internal, blue throughout. The same botanist made further experiments with numerous plants, which he first caused to absorb ferrocyanide of potassium, and of which he afterwards made sections, which he placed in a solution of sulphate of iron, because he found this more convenient and more certain, than when he allowed them to imbibe the latter solution. The results which he deduces from his inquiries are—1. That in cellular plants without a central series of elongated cells, there is no special organ for the transmission of sap. Mr. Honninger made his observations only on lichens, not on other cellular plants. 2. That in all vascular plants the sap is carried upwards solely through the vessels (tubular tissue). The grounds for this last proposition are so conclusive, that Link thinks we may look upon it as a settled question.

The accumulation of sap in plants appears to be attended with very beneficial consequences, and to be deserving of the especial attention of gardeners. It is well known how weak and imperfect is the inflorescence of the Turnip tribe forced to flower before their fleshy root is formed; and how vigorous it is after that reservoir of accumulated sap is completed. Knight, in a valuable paper upon this subject, remarks that the fruit of Melons, which sets upon the plant when very young, uniformly falls off; while, on the contrary, if not allowed to set until the stem is well formed, and much sap accumulated for its support, it swells rapidly, and ripens without experiencing any deficiency of food in the course of its growth. In like manner, if a fruit tree is by any

circumstance prevented bearing its crop one year, the sap that would have been expended accumulates, and powerfully contributes to the abundance and perfection of the fruit of the succeeding year.

The cause of the motion of the sap is a subject which has greatly excited curiosity, and given rise to numberless conjectures. It was for a long time believed that there was a sort of circulation of the sap of plants, to and from a common point, analogous to that of the blood of animals; but this was rendered improbable by the well-known fact that a plant is more analogous to a polype than to a simple animal; that it is a congeries of vital systems, acting indeed in concert, but to a certain degree independent of each other, and that, consequently, it has myriads of seats of life. It was, moreover, experimentally disproved by Hales. This excellent observer, whose *Statics* are an eternal monument of his industry and skill, thought that the motion of the sap, the rapidity of which he had found to be greatly influenced by weather, depended upon the contraction and expansion of the air, which exists in great quantities in the interior of plants. Others have ascribed the motion to capillary attraction. Knight was once of opinion that it depended upon a hygrometrical property of the plates of silver grain (medullary rays), which traverse the stem in all directions. The same physiologist considered that the mechanical agitation of stems and branches by wind was favourable to the motion: he confined the stem of a tree, so that it could vibrate only in one plane; and, at the end of some years, he observed that its section was an ellipse, whose greater axis lay in this plane. Other theorists have called to their aid a supposed irritability of the vessels; but no contraction of the vessels has ever yet been noticed, except under the influence of frost, as shown by Biot. Du Petit Thouars suggests that it arises thus:—In the spring, as soon as vegetation commences, the extremities of the branches and the buds begin to swell: the instant this happens a certain quantity of sap is attracted out of the circumjacent tissue for the supply of those buds: the tissue, which is thus emptied of its sap, is filled instantly by that beneath or about it: this is in its turn replenished by the

next; and thus the whole mass of fluid is set in motion, from the extremities of the branches down to the roots. Du Petit Thouars is, therefore, of opinion that the expansion of leaves is not the effect of the motion of the sap, but, on the contrary, is the cause of it; and that the sap begins to move at the extremities of the branches before it stirs at the roots. That this is really the fact, is well known to foresters and all persons accustomed to the felling or examination of timber in the spring; and to gardeners who are occupied with forcing the branches of plants in winter, while their trunks are exposed to the weather. Some good observations upon this were communicated to Loudon's *Gardener's Magazine*, by Mr. Thomson, gardener at Welbeck; who, however, drew a wrong inference from them.

The following observation gives additional weight to the opinion of Du Petit Thouars:—

M. Gaudichaud found, when in Brazil, that, upon cutting through one of the creeping Cissi (C. hydrophora), the sections only slightly discharged fluid when the upper part was merely divided from the under; but that when a truncheon, of whatever length, was separated from the stem, the sap then ran out in great quantity from either end, according to which was held downwards, and that it only dropped out slowly when held in a horizontal position. Upon examining the next day the cut end of the lower part of this stem, it was found dry for 5 or 6 inches below the wound. M. Gaudichaud ascribes the latter circumstance to the pressure of the atmosphere upon the orifices of the tubes; and the absence of any considerable amount of bleeding in the upper half, to the power of suction in the leaves, &c.; while he attributes the ready discharge of fluid from either end of the separated truncheon to atmospheric pressure, which, he supposes, operates upon the vessels of the Cissus, as it would upon inert tubes. (*Ann. Sc.*, n. s., vi. 142.)

Dutrochet has formed a theory of all the motions of fluids in plants depending upon the agency of galvanism. He found that small bladders of animal and vegetable membrane, being filled with a fluid of greater density than water, securely fastened, and then thrown into water, acquired weight; he

also remarked, that if the experiment was reversed, by filling them with water and immersing them in a denser fluid, the contrary took place, and that the bladders lost weight. He took a small bladder, and filled it with milk, or gum arabic dissolved in water; to the mouth of this bladder he adapted a tube, and then plunged the bladder in water: in a short time the milk rose in the tube, whence he inferred that water had been attracted through the sides of the bladder. This experiment was also reversed, by filling the bladder with water, and plunging it in milk: the fluid then fell in the tube, whence he inferred that water had been attracted through the coat of the bladder into the milk. From these and other experiments, Dutrochet arrived at the inference, that, if two fluids of unequal density are separated by an animal or vegetable membrane, the denser will attract the less dense through the membrane that divides them: and this property he calls *endosmose*, when the attraction is from the outside to the inside; and *exosmose*, when it operates from the inside to the outside. In pursuing this investigation, he remarked that, if an empty bladder is immersed in water, and the negative pole of a galvanic battery introduced into it, while the positive pole is applied to the water on the outside, a passage of fluid takes place through the membrane, as had previously happened when the bladder contained a fluid denser than water; by reversing the experiment, the reverse was found to take place: from all which Dutrochet deduces the following theory:—That, when two fluids of unequal density are separated by an intervening membrane, the more dense is negatively electrified, and the less dense positively electrified; in consequence of which, two electric currents of unequal power set through the membrane, carrying fluid with them; that which sets from the positive pole, or less dense fluid, to the negative pole, or more dense fluid, being much the more powerful: and that the fluids of plants being more dense than those which surround them, a similar action takes place between them and the water in the soil, by means of which the latter is continually impelled into their system. Philosophers do not seem disposed to admit the legitimacy of Dutrochet's conclusion, that this transmission takes place

by means of galvanic agency; but that the phenomenon is correctly described by the ingenious author, and that it is constantly operating in plants, are beyond all dispute. It is by endosmose that vapour is absorbed from the atmosphere, and water from the earth; that sap is attracted into fruits by virtue of their greater density; and, probably, that buds are enabled to empty the tissue that surrounds them, when they begin to grow.

But, although endosmose will be found a ready explanation of many of the phenomena connected with the ordinary movement of fluids, it throws no light upon rotation, which, so far as we at present know, is a motion inexplicable upon any principle yet discovered, and it by no means dispenses with the vital force which, after all, offers the best explanation of most of the phenomena of life.

Of Rotation.

This kind of motion is confined to plants of a low organisation, but not entirely to flowerless or cellular families. It, however, forms for Professor Schultz an important physiological means of separating the vegetable kingdom into two primary classes, namely, *Homorgana* and *Heterorgana:* the former of which, consisting wholly or in great measure of cellular tissue, contains all the cellular flowerless, and some flowering plants of a low organisation; the latter all the higher flowering plants, and the vascular flowerless. It consists in a special circulation of the fluid contained in the interior of each cell, and is always so limited; the rotation in one cell never interposing or mixing with that in another cell. The rotating sap of such plants is said by Schultz to have the power of absorbing coloured fluids, while the cinenchymatous vessels, in which what he calls cyclosis goes on, either do not take up any coloured fluid, or, at least, not till they receive it in an altered state from other forms of tissue.

Corti, in 1774, Fontana, L. C. Treviranus, and especially Amici, made the earliest observations upon rotation. It was found that if a portion of Nitella flexilis, or even of the crustaceous Charas, their opaque cuticle being first scraped away,

be examined, a current of sap will be distinctly seen in each cellule, setting from joint to joint, flowing down one side and returning up the other, without any membrane intervening to separate the opposing currents; each cellule has a movement of its own, independent of that of the cellules above and below it; sometimes the movement stops, and then goes on again after a brief interval; if a cellule is divided into two by a ligature passed round it, a separate movement is seen in each of the divisions; this motion is rendered distinctly obvious by the numerous minute green granules which float in the transparent fluid, and which follow the course of the currents. —The observations of Amici have been verified and much extended by subsequent investigations.

Among other things, it has been ascertained that in Nitella the currents have always a certain relation to the axis of growth, the ascending current uniformly passing along the side of the cell most remote from the axis, and the descending current along the side next the axis.

Mr. Varley considers (*Trans. Soc. Arts*, xlix. p. 20.) that, in addition to the principal current, which he finds setting up one side and down the other within the green interior granular sac of each joint of Chara, there are two others, of which one takes place between the side of the interior sac and the side of the outer transparent coating, the other current is said to occur in the centre of the interior cell, and to be very sluggish.

A further and very detailed examination of the Chara fragilis has been made by M. Dutrochet, the general results of which are to be found in the *Ann. des Sciences*, n. s., vol. ix. p. 73. It appears from them, among other things, that experiments, expressly instituted by M. Becquerel, show the motion *not* to be owing to a voltaic action of the green globules lining the cells, nor to any known form of electrical agency, but to vital force; and, also, that the rapidity of the movement is increased by an elevated, and diminished by a lowered, temperature, the mean rate of motion of the swimming granules being a millimetre ($\frac{443}{1000}$ of a line) in 35 or 36 seconds.

Similar motions have been seen in several other plants.

In the cells of Hydrocharis Morsus-Ranæ the fluid has been observed to move round and round their sides in a rotatory manner, which, however, has not been seen to follow any particular law.

Pouchet and Meyen (*An. Sc.*, n. s., iv. 257.) have remarked it in the longer cells of the stem of Zannichellia palustris, and the latter in Vallisneria, Stratiotes, Potamogeton, and the radical hairs of Marchantia. It may be distinctly seen in Equisetum. According to Schultz (*Arch. Bot.* ii. 425.), it is also visible in Podostemads, Ceratophyllum, Naiads, Sea-wracks, Lemna, Mosses, Liverworts, Lichens, Algals, and Fungals. The rotation in Vallisneria canadensis is most beautiful. In large cylindrical cells filled with a transparent fluid, there float large brilliantly green spherules, which rotate up one side and down another with a slow motion, sometimes crowding together, sometimes distant, and occasionally stopping. There is, moreover, among the woody tubes, a more rapid movement of very minute oval bodies, which goes on in lines upwards and downwards.

According to Meyen, the granules seen moving in the rotating currents are of different kinds (*Ann. Sc.*, n. s. iv. 261.), the larger being grains of starch, others vesicles slightly coloured by chlorophyll, and some being drops of oil. I find but little trace of fæcula in Vallisneria, tincture of iodine chiefly producing a brown colour upon the granules, but here and there a blue centre was visible.

By no one have the phenomena of rotation been described with more accuracy than by Professor Mohl. "When the protoplasm," he says, "has assumed the form of filaments, a current may almost always be observed in them. This may, of course, be easily detected when readily perceptible globules are contained in the currents, as in the filamentary hairs of Tradescantia, in the stinging hairs of Urtica, in the hairs of the Melon, &c.; but where, on the contrary, this is not the case, and the filaments consist of a very homogeneous transparent mass, as for instance, in the hairs of Alsine media, the existence of the current can only be inferred from the change of position in the filaments. With respect to this alteration in the position of the currents, the cessation of

some and the origin of others at fresh places where none previously existed, this phenomenon has been already described by others, especially by Meyen and Schleiden.

"The following phenomena, which I observed on the stinging hairs of Urtica baccifera, yield, together with this change of position of the sap, current, and nucleus, a further proof against the existence of a vascular system or inner cells. I left a leaf of this plant lying for a couple of days on the table, so that, with the exception of the large ribs and the stinging hairs situated on it, it was perfectly dry. Now in these faded hairs the currents appeared to be very much altered; some still existed in the natural state and were in motion, but in the greater portion the granules had separated, and were distributed with tolerable uniformity over the surface of the cellular membrane, and exhibited a molecular motion. When some of the hairs which had been cut off had lain in water for half an hour and were again full of sap, the granules arranged themselves more and more into filaments, between which were some free spaces and in which the circulating motion was completely restored. In this case, therefore, every possibility of the currents being inclosed between membranes is excluded; indeed the form of the currents of sap, as exhibited in the stinging hairs of this plant, is opposed to that view. The movement of the current is mostly very irregular; if we leave Chara out of the question, it is most regular in Vallisneria, but even here it is far from being uniform. The sap flows quicker in one cell than in another, in one current quicker than in the adjacent; frequently stoppages occur at some spots, so that the sap becomes increased for a time, and some granules are overtaken by those behind them, &c. This inequality of the motion renders the determination of the velocity of the current somewhat uncertain, or rather it compels us to make a larger series of admeasurements and to draw the mean from them. Since, as far as I am aware, no observations have been published on the velocity of this motion excepting in Chara, the following statements may not be considered out of place:—I have only to observe, that all these admeasurements were made at a temperature of 66° to 68° Fahr., and that the influence which

different temperatures exert on the phenomenon has not yet been investigated. In filamentary hairs of Tradescantia virginica the velocity of the current varied from $\frac{1}{300}$ to $\frac{1}{900}$ Par. lin. in a second; the mean was $\frac{1}{500}$. In the leaves of Vallisneria spiralis the quickest motion was $\frac{1}{125}$, the slowest $\frac{1}{600}$, and the mean $\frac{1}{185}$ line. In the stinging hairs of Urtica baccifera the quickest motion was $\frac{1}{625}$, the slowest $\frac{1}{875}$, the mean $\frac{1}{730}$ line. In the cellular tissue of a stolon of Sagittaria sagittifolia the velocity varied between $\frac{1}{726}$ and $\frac{1}{1056}$, and amounted on the average to $\frac{1}{854}$; in the leaf of the same plant it varied between $\frac{1}{1170}$ and $\frac{1}{1360}$, the average being $\frac{1}{1253}$ line. In the hairs of Cucurbita Pepo the quickest movement amounted to $\frac{1}{770}$, the slowest to $\frac{1}{2760}$, the average being $\frac{1}{1857}$ line. The smallness of these numbers will probably surprise many, especially when they are compared with the apparently considerable velocity which the circulation of the sap, in Vallisneria for instance, exhibits under the microscope. But it must not be forgotten, that in these observations the motion is seen quickened several hundred times. The above admeasurements were made in the following manner: while I observed the passage of the image of the globule across the field of a glass micrometer fixed in the ocular, I counted the strokes of a second-pendulum. What the nature of the granules floating in the protoplasm may be, cannot in most cases be ascertained on account of their minute size; but it appears that they are in all cases coloured yellow by iodine, and are, therefore, most probably nitrogenous. When granules of chlorophyll occur in the cells, they are situated either, as for instance is the case in the hairs of the Melon, isolated and close to the walls of the cells without having any definite relation to the current, and only a few move on with the current, or they are all connected with the current and move with it, as in Stratiotes aloides and Sagittaria sagittifolia. This form effects the transition to Vallisneria, in whose cells it is not the cellular sap itself which is in rotation, as appears at first sight, but a mucilaginous fluid with which the chlorophyll granules and the nucleus are connected, and which flows in an uninterrupted current along the cell-walls, but on account of its great

transparency and slight thickness is not very easily seen. Likewise in Chara it is not, as is generally supposed, the cell-sap itself which moves, but a denser fluid present in large quantity and occupying the outer parts of the cell-cavity, as has been already shown by other observers." (*Annals of Natural History,* 18. 6.)

Of Cyclosis.

In the first volume, a particular kind of tissue, called cinenchym, or vessels of the latex, has been mentioned. It is in this description of tissue that the phenomenon of what is called cyclosis takes place. The detailed statements of Professor Schultz of Berlin, from whom, almost exclusively, the description of this phenomenon has originated, are as follows:—

1. The phenomenon of cyclosis *consists* of a motion of fluid called *latex,* usually more or less milky, but often transparent, which conveys granular matter through a plexus of reticulated vessels, in all directions; when the vessels are parallel and near each other, the currents rise in some and fall in others, but, in connecting or lateral vessels, the currents are directed from right to left, or the reverse, according to no apparent rule. The contiguous rows of vessels anastomose from place to place; which produces a permanent interruption of the rising and falling currents. In order to enable a circulating motion to take place, it is necessary that the system of vessels should be reticulated, as takes place in the peripherical vascular system of animals. The vessels contract and become so small as to be invisible, they then fill themselves again, enlarge, and re-establish the communication which had been interrupted. It often happens that when strong currents are formed, the weak ones disappear. If a current is about to stop, it may be seen to oscillate a moment both in front and rear. If the globules are amassed in a particular place, an obstruction takes place, and the fluid part of the latex is no longer capable of passing along. If we take a thin slice of bark, or better still, certain entire organs, very thin, transparent, and young, but fully formed, in which the latex has an abundance of globules, it is often

easy to observe a translation of fluid, and to appreciate its rate of motion, by the time which the globules take in moving a certain space. In cases where the motion of cyclosis cannot be actually seen in the vessels, it may be inferred from the following fact. When the two ends of a stem containing milk are cut through, the latex is seen to run out at both ends of the fragment, which proves that there must be both an ascending and descending current: the same phenomenon is visible in plants having a colourless latex; therefore there must be a motion of ascent and descent in them also.

2. It *occurs* in the greater part of monocotyledonous and dicotyledonous plants, and the vessels in which it takes place, are so generally in connection with spiral vessels, that the presence or absence of the one is usually accompanied by that of the other. The situation of the vessels in which it is found is, in the root, stem, petiole, peduncle, flower, &c. The system of vessels, in the form of a delicate network, surrounds the cells, and even traverses their interior, in the most diverse directions. In the stems of monocotyledons, cyclosis occurs in the woody bundles, as also in those dicotyledons which have their wood in like manner separated into distinct cords. But, in the stems of dicotyledons where the wood is disposed concentrically, the vessels of the latex are either placed singly, in the parenchyma of the bark; or, which is most common, they either form a continuous envelope around the wood, or bundles arranged circularly, or even scattered cords. Vessels of latex may even be found in the pith. Schultz finds them in communication with the curious glands which in Nepenthes line the pitcher, and secrete the water found therein. In the form of capillary vessels (vasa contracta), they are very commonly present in hairs, where they form a most delicate plexus. It is, however, difficult to prove that the streams visible in hairs are really ramifications of cinenchyma, and Meyen has even denied their existence, upon which M. Schultz says with some asperity: "Wonderful enough, he has had them before his eyes, everywhere, in the fine anastomosing streams in which the sap circulates in the cells, without recognising

them. These vessels pass through and round the different organs, particularly the cells of the secreting organs, like a fine spider's web, and are visible in many plants, for example, in the species of Caladium and Arum, even after maceration."

3. The latex is a highly elaborated and highly organised juice, which is not formed immediately from the fluid nutrient matter absorbed from without. It is usually viscid, insoluble in water, often opake, coloured white, yellow, red, brown, and is also often transparent and colourless; differences that result from the nature of the organised globules it contains, which, according to M. Schultz, *constitute the living part of the latex.* These globules have an oscillating motion, and, like the globules of blood, they coagulate, and the liquid part becomes transparent. In many plants which, when old, have a milky latex, it is colourless when they are young; this depends upon the degree of concentration of the latex. Upon exposure to the air, latex separates into a *coagulum* of a tenacious elastic quality, and a *serum*, the former being sometimes analogous to caoutchouc. This property is not found in any other vegetable secretions. If we consider the organisation of the latex, the globules it contains, its property of coagulating and separating into serum and a sort of fibrine, we are tempted to believe that there exists a considerable analogy between it and the blood of animals. By these marks the latex may be known from ethereal oil, resin, gum, and other secretions sometimes found in the interior of parenchyma, and which are always transparent and destitute of globules. Nevertheless, Link has unaccountably confounded with cinenchyma the turpentine vessels of Conifers. (*Elementa,* ed. 2., i. 196.)

4. The latex itself *originates* in the sap, which rises by the tissue of the wood, and introduces itself into the foliaceous organs, thence, after being elaborated, passing into the bark, where it is deposited in the vessels in its mature form. De la Baisse caused a Euphorbia to pump up water coloured red; the liquid ascended in the wood, reached the leaves, tinged the latex, and the colour spread from above downwards in the bark: but M. Schultz only twice succeeded, after many attempts, at obtaining this result.

5. The *function* of the latex is to nourish the tissue among which it is found. Increase in the layers of wood and bark may be arrested, if by ligatures, or cutting off annular portions of the bark, the afflux of nutritious particles from above downwards is stopped. Now the latex is the only one of the fluids in the bark which can have a progressive motion, and it is therefore it which furnishes nutrition. Upon robbing Asclepias syriaca of a great quantity of its milk, it ceased to bear fruit, but it sustained no inconvenience upon merely losing its sap. In fact, the loss of only small quantities of latex injures plants very much. It is the phenomenon of *autosyncrasis* and *autodiacrasis* (attraction and repulsion of the globules) which produces assimilation and nutrition. In consequence of autodiacrisis, the molecules of latex escape through the sides of its vessels, to be conveyed to the parts requiring nutriment; while, on the contrary, autosyncrisis brings about the assimilation of the nutritious matter. In proof of which, it is found that the distribution of latex is most abundant in those parts where the greatest increase ought to take place, and that the rapidity of the cyclosis is greatest at the periods of development, the temperature remaining the same.

6. The *cause* of the motion may be assigned to *heat;* for, when Acer platanoides was exposed to a temperature of 18° to 24° centig. (—2° to 11° Fahr.), the latex ceased to move, but the motion was re-established when it was brought into a warm room: to *endosmose;* for water will sometimes cause a renewal of motion when it has stopped: to *light;* because that agent determines the direction of growth: to *contraction,* which is the effect of irritability; not however a contraction with successive pulsations, as in arteries, but by a simultaneous action throughout the whole length of the vessel, whose latex is thus brought into a state of powerful tension. Contraction, however, cannot be the first cause of the motion, for it is not even sufficient to change the direction of the currents. When a vessel has been cut through at both ends, it has discharged all its contents by that end to which the current had been directed, and not by the other. But these are to be regarded as secondary causes only; the essential cause is the perpetual

oscillation of the globules. They have an incessant tendency to unite and to separate, without the one tendency ever overcoming the other; and, as the organic (molecules) elements of vessels are of the same nature as the globules of latex, it follows that the walls of the vessels, and the globules they contain, have the same tendency to approach and retreat, as the globules themselves have with respect to each other. As this motion of coming and going takes place in a determinate direction, it necessitates and regulates the progressive motion of the latex.

7. Cyclosis is *analogous* to the motion of the blood in the lower animals, such as Nephelis vulgaris, Planarias, Nais proboscidea, and Diplozoon paradoxum; or in the fœtus of a fowl, before the heart is formed, when, as Malpighi and Wolff have shown, the blood moves spontaneously in the vascular apparatus. Nevertheless, although there is in plants no heart, or centre of circulation, according to M. Schultz, there are certain foci, concerning which he speaks thus (*Comptes rendus,* vi. 583.) :—In Commelina cœlestis there is a bundle of laticiferous vessels, which are very delicate and filamentous, compact and united in the form of a net with very long meshes, in which are perceptible currents of latex ascending, descending, and returning upon itself. Besides, at the side of the focus, in the cellular tissue, we remark the cyclosis in distant currents, and the same thing is visible between the cells of the hair. It is observed that the scattered currents, whether in the cellular tissue of the stem, or in the hairs, are neither separate in each cell nor isolated throughout the cellular tissue, but united to the focus of circulation in certain places; so that all the latex circulating in the cellular tissue and the hairs is derived from the focus of the cyclosis. The same things are still more distinctly visible in Campanula rapunculoides.

Cyclosis may be easily seen in the stipules and bark of the Fig, especially of Ficus elastica; in the leaves, and even the valves of the fruit, of Chelidonium; and in the bark of Acer platanoides. In no case, however, is it seen more easily than in the interior sepals of Calystegia sepium, which are thin enough to bear examination, without laceration,

when viewed by transmitted light. In the larger vessels (vasa expansa) the latex appears stationary; but in the smaller ramifications it is seen to move rapidly or slowly, by starts or in a steady current, carrying along with it single globules or several together, which are forced along the passage in the vessels, much as pieces of wood might be expected to be carried in water through a narrow and sinuous channel. It looks as if the matter of the latex met with frequent obstructions, which stopped the current for a moment and then gave way, when a rapid flow goes on till it is again interrupted. Professor Morren has also mentioned the young flowers and receptacle of the common Fig, as an extremely easy subject in which to find the motion.

If, however, the fine capillary ramifications of the cinenchyma upon the surface of plants will satisfy the enquirer, the movement of cyclosis may be readily found in almost any lymphatic hair, provided the microscope employed will magnify 350 diameters. Tradescantia virginica is usually employed for this purpose, but in reality any hair will show it, especially if the latex be milky. It is then seen, to use the words of my lamented pupil, Mr. Slack, that each joint of the hair consists of an outer glassy colourless case, enclosing the colouring matter. A nucleus (cytoblast) is situated at the base of the joint, and currents of small particles appear to pass near it or over its surface. Those currents may often be traced through their whole course around the cell, ascending in one part, descending in another, and sometimes two uniting into one. The structure of each joint of the hair appears to be an outer glassy tube, with longitudinal striæ; between this and the colouring matter the moving fluid with its particles exist. The coloured fluid of the hair seems to be enclosed in a membranous sac, which forms an axis round which the moving fluid revolves. The cytoblast must also be external to the sac, as it is in connection with the currents. (*Trans. Soc. Arts,* xlix. p. 41).

The best and most recent observations upon latex do not confirm Professor Schultz's views. Admitting his statements to be essentially true his conclusions are disputed. In particular Professor Mohl has obtained results which make

M. Schultz's theory of the latex appear erroneous. "By placing a small quantity of latex between two slips of glass, and sliding these over one another, it may easily be seen that the globules are composed of a softish, very viscid matter, that pressure unites them, and that there is no trace of an enveloping membrane; they may be collected and drawn out in a stringy mass, beneath the microscope, with the point of a fine needle. When a thin layer of latex is dried on glass, the liquid in which the globules float is changed into a transparent crust, which may be dissolved in water so as to re-establish the original condition of the sap. This dried serum forms a brittle mass, which, like a thin layer of gum, breaks with sharp angles, while the globules retain their original form and condition. When this dried mass is exposed to the air for about twenty-four hours, particularly if placed in the sun, the elastic substance of which the globules are composed contracts in the cavities of the serum, presenting the appearance of vesicular membranes containing nuclei; but the solution of the serum in water clearly proves this to be an illusion." Thus it is "seen that the globules are destitute of any trace of organisation, and can no more be compared with blood-corpuscles than can any other drops of resin, oil, &c., met with in vegetable fluids. The caoutchouc of the latex cannot be compared with the fibrine of the blood, since it is not met with, as that is, in solution in the serum, and does not transform this latter into a plasma; it is met with, on the contrary, in a complete state of development under the form of globules.

The mutual attraction and repulsion of the globules and the walls of the vessels, the autosyncrasy and autodiacrasy of M. Schultz, Professor Mohl sets down as pure creations of fancy. He says that they are nothing more than ordinary molecular motion, and take place equally in fresh latex and that which has been diluted with water or dried and re-dissolved. The movement in the form of a current is, according to M. Schultz, independent of external influences; Professor Mohl states that the latex in its natural condition is in a state of absolute repose. By bringing portions of uninjured plants of Chelidonium beneath the microscope, he found that

while the connexion between the leaf under examination and the rest of the plant was unbroken, a current could generally be perceived which lasted for about half a minute and then gradually ceased; he satisfied himself that this was produced by the torsion and compression of the vessels of the neighbouring parts. When the petiole was cut across, a very rapid current took place towards the wound, which continued until the coagulation of the extravasated latex closed the wounded vessels. On cutting a little further up, the current was set up again. In the leaves of Tragopogon mutabilis, where the principal nerves take a rectilinear direction, the current could be made to flow from the summit to the base, or from the base to the summit of the leaf, according as the apex or the petiole of the leaf was cut off. The slightest pressure, also, affected the direction of the current."

BOOK III.

GLOSSOLOGY; OR OF THE TERMS USED IN BOTANY.

In order to comprehend the language of botanists, it is necessary that the unusual terms or words which are employed in writing upon plants, and which are either different from words in vulgar use, or which are in Botany employed in a particular sense, should be fully explained.

It is a very common plan to mix up Glossology with Organography, or to confound the definition and explanation of those characteristic terms of the science which are universally applicable, with the description of particular organs: but this plan is attended with many inconveniences, and is far less simple than to treat of the two separately. It was an error into which Linnæus fell, in composing his admirable *Philosophia Botanica;* and is the more remarkable, if the logical precision with which that work is otherwise composed be considered. Instead of distinguishing those terms which have a general application to all plants or parts of plants, according to circumstances, from such as have a particular application, and relate only to special modifications, he placed under his definition of each organ those terms which he knew to be applicable to it; but, as it was not his practice to repeat terms after they had been once explained, it frequently happened that beginners in the science, finding a given term explained once only, and with reference to a particular organ, fell into the mistake of supposing that that term was applicable only to the organ under which it was explained. To avoid this difficulty, other botanists have collected under each organ all the terms which could by possibility be applied to it, and have repeated them over and over again without regard

to previous definitions; as if they supposed it impossible to convey by words an idea of the meaning of any term whatever, without noticing at length every possible application of it. Thus, in Willdenow's *Principles of Botany*, the most common and simple terms are repeated five, six, and even seven times; and in a more modern work, of very high character (*Les E'lémens de Physiologie Végétale et de Botanique*, by Mirbel), the same practice has been carried so far, that the application of the word *simple* is explained in twenty-three different instances.

The true principles of arranging the glossology of science have, however, been long before the public. In the year 1797, Link, in his *Prodromus Philosophiæ Botanicæ*, distinguished the characteristic or common terms used in Botany from those which applied only to particular organs; and his example was afterwards followed by Illiger, a learned German naturalist, who, in the year 1810, proposed a total reformation of the method of describing the terms employed in Natural History (see his *Versuch einer Systematischen vollständigen Terminologie für das Thierreich und Pflanzenreich*). Little attention, however, was paid to the principles of these writers till the year 1813; when De Candolle adopted them in his *Théorie E'lémentaire de la Botanique*, with his accustomed skill and sagacity.

The characteristic terms of Botany are those which have a general application to any or all of the parts of plants, and must not be confounded with such as have a particular application only, which will be found under the organs to which they respectively belong: the former are either *individual* or *collective*; of which the first apply to plants, or parts of plants, considered abstractedly; the second to plants, or their parts, considered in masses. To these are to be added those syllables and marks which, either prefixed or affixed to a known term, occasion an alteration in its signification. These I call *terms of qualification*. In the following arrangement, those terms which are seldom used are marked with a †; and those are entirely omitted which are used in Botany in their common acceptation.

CHARACTERISTIC TERMS are either * INDIVIDUAL or ‡ COLLECTIVE.

CHARACTERISTIC INDIVIDUAL TERMS are either *Absolute* or *Relative*.

* *Individual Absolute Terms* relate to,—

1. Figure.
   - A. with respect to general form.
   - B. outline.
   - C. the apex or point.
2. Division.
   - A. with respect to the margin.
   - B. incision.
   - C. composition or ramification.
3. Surface.
   - A. with respect to marking or evenness.
   - B. appendages.
   - C. polish.
4. Texture.
5. Size.
6. Duration.
7. Colour.
8. Variegation.
9. Veining.

* * *Individual Relative Terms* comprehend,—

1. Estivation.
2. Direction.
3. Insertion.
   - A. with respect to the mode of attachment or of adhesion.
   - B. situation.

‡ *Collective Terms* relate to,—

1. Arrangement.
2. Number.

Class I. OF INDIVIDUAL TERMS.

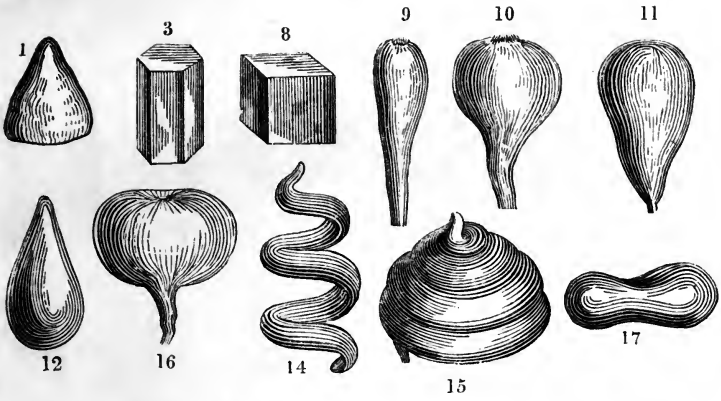
The terms which are included in this class are applied to the parts of a plant considered by themselves, and not in masses; they are either *absolute*, being used with reference to their own individual quality; or *relative*, being employed to express the relation which is borne by plants, or their parts, to some other body. Thus, for example, when we say that a plant has a *lateral ovate* spike of flowers, the term *lateral* is relative, being used to express the relation which the spike bears to the stem; and the term *ovate* is absolute, being expressive of the actual form of the spike: and, again, in speaking of a *rugose terminal* capsule, *rugose* is absolute, *terminal* is relative.

I. *Of Individual Absolute Terms.*

These relate to figure, division, surface, texture, size, duration, colour, variegation, and veining.

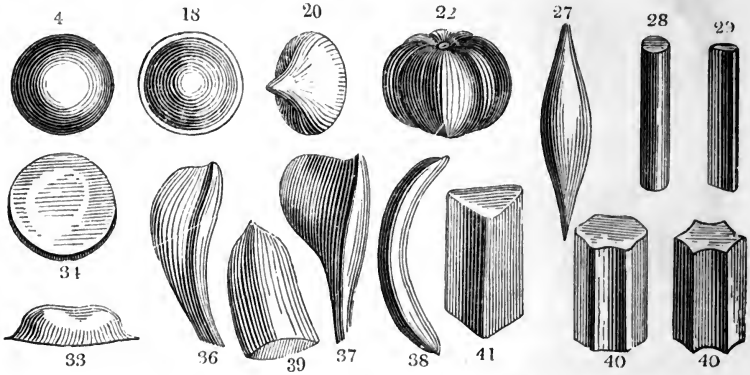
1. Of Figure.

A. *With respect to General Form.*



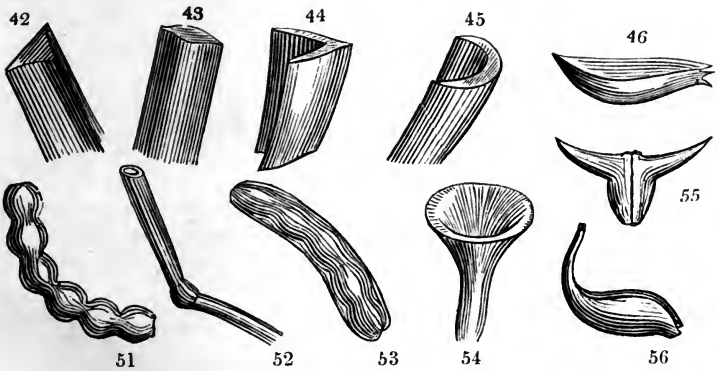
1. Conical (*conicus*, † *pyramidalis*) ; having the figure of a true cone ; as the prickles of some Roses, the root of Carrot, &c.
2. Conoidal (*conoideus*) ; resembling a conical figure, but not truly one ; as the calyx of Silene conoidea.
3. Prism-shaped (*prismaticus*) ; having several longitudinal angles and intermediate flat faces ; as the calyx of Frankenia.
4. Globose (*globosus, sphæricus*, † *globulosus*) ; forming nearly a true sphere ; as the fruit of Ligustrum, many seeds, &c.
5. Cylindrical (*cylindricus*) ; having nearly a true cylindrical figure : as the stems of Grasses, and of most monocotyledonous plants.
6. Tubular (*tubulosus*, † *tubulatus*) ; approaching a cylindrical figure, and hollow ; as the calyx of many Silenes, &c.
7. Fistulous (*fistulosus*) ; this is said of a cylindrical or terete body, which is hollow, but closed at each end ; as the leaves and stems of the Onion.
8. Cubical († *cubicus*) ; having or approaching the form of a cube : a very rare form, chiefly occurring in some seeds, as that of Vicia lathyroides.
9. Club-shaped (*clavatus*, † *claviformis*) ; gradually thickening upwards from a very taper base ; as the appendages of the flower of Schwenkia, or the style of Campanula and Michauxia.
10. Turbinate, or top-shaped (*turbinatus*) ; inversely conical, with a contraction towards the point ; as the fruit of some Roses.
11. Pear-shaped (*pyriformis*) ; differing from turbinate in being more elongated ; as in many kinds of Pears.
12. † Tear-shaped († *lachrymæformis*) ; the same as pear-shaped, except that the sides of the inverted cone are not contracted ; as the seed of the Apple.
13. † Strombus-shaped († *strombuliformis*) ; twisted in a long spire, so as to resemble the convolutions of the shell called a Strombus ; as the pod of Acacia strombulifera, or Medicago polymorpha.
14. Spiral (*spiralis*) ; twisted like a corkscrew.

15. Cochleate (*cochleatus*) ; twisted in a short spire, so as to resemble the convolutions of a snail-shell ; as the pod of Medicago cochleata.
16. Turnip-shaped (*napiformis*) ; having the figure of a depressed sphere ; as the root of the Turnip-Radish, &c.
17. † Placenta-shaped († *placentiformis*) ; thick, round, and concave, both on the upper and lower surface ; as the root of Cyclamen.



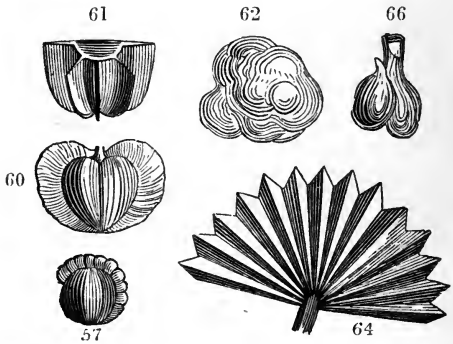
18. Lens-shaped (*lenticularis, lentiformis*) ; resembling a double convex lens ; as the seeds of Amaranthus.
19. Buckler-shaped (*scutatus, scutiformis*) ; having the figure of a small round buckler ; as the scales upon the leaves of Elæagnus.
20. Bossed (*umbonatus*) ; round, with a projecting point in the centre, like the boss of an ancient shield ; as the pileus of many species of Agaricus.
21. Gibbous (*gibbus, gibbosus*) ; very convex or tumid ; as the leaves of many succulent plants : this term should be restricted to solid convexities.
22. † Melon-shaped († *meloniformis*) ; irregularly spherical, with projecting ribs ; as the stem of Cactus Melocactus : a bad term.
23. Spheroidal (*sphæroideus*) ; a solid with a spherical figure, a little depressed at each end. *De Cand.*
24. Ellipsoidal (*ellipsoideus*) ; a solid with an elliptical figure. *De Cand.*
25. Ovoidal (*ovoideus*) ; a solid with an ovate figure, or resembling an egg.
26. Shield-shaped (*clypeatus*) ; in the form of an ancient buckler : the same as scutate, No. 19.
27. Spindle-shaped (*fusiformis, † fusinus*) ; thick, tapering to each end ; as the root of the long Radish. Sometimes conical roots are called fusiform, but improperly.
28. Terete, or taper (*teres*) ; the opposite of angular : usually employed in contradistinction to that term, when speaking of long bodies.
29. Half-terete (*semiteres*) ; flat on one side, terete on the other.
30. Compressed (*compressus*) ; flattened lengthwise ; as the pod of a Pea.
31. Depressed (*depressus*) ; flattened vertically ; as the root of a Turnip.
32. Plane (*planus*) ; a perfectly level or flat surface ; as that of many leaves.
33. Cushioned (*pulvinatus*) ; convex, or rather flattened : seldom used.
34. Discoidal (*discoideus*) ; orbicular, with some perceptible thickness, parallel faces, and a rounded border ; as the fruit of Strychnos Nux-vomica.

35. Curved (*arcuatus, curvatus*) ; bent, but so as to represent the arc of a circle ; as the fruit of Astragalus hamosus, Medicago falcata, &c.
36. Scimitar-shaped (*acinaciformis*) ; curved, fleshy, plane on the two sides, the concave border thick, the convex border thin ; as the leaves of Mesembryanthemum acinaciforme.
37. Axe-shaped (*dolabriformis*); fleshy, nearly straight, somewhat terete at the base, compressed towards the upper end ; one border thick and straight, the other enlarged, convex, and thin ; as the leaves of Mesembryanthemum dolabriforme.
38. Falcate (*falcatus*); plane and curved, with parallel edges, like the blade of a reaper's sickle ; as the pod of Medicago falcata: any degree of curvature, with parallel edges, receives this name.
39. Tongue-shaped (*linguiformis*); long, fleshy, plano-convex, obtuse ; as the leaves of Sempervivum tectorum, and some Aloes.
40. Angular (*angulosus*) ; having projecting longitudinal angles. We say *obtuse-angled* when the angles are rounded, as in the stem of Salvia pratensis ; and *acute-angled* when they are sharp, as in many Carices. Some call these angles the *acies*.
41. Three-cornered (*trigonus*) ; having three longitudinal angles and three plane faces ; as the stem of Carex acuta.



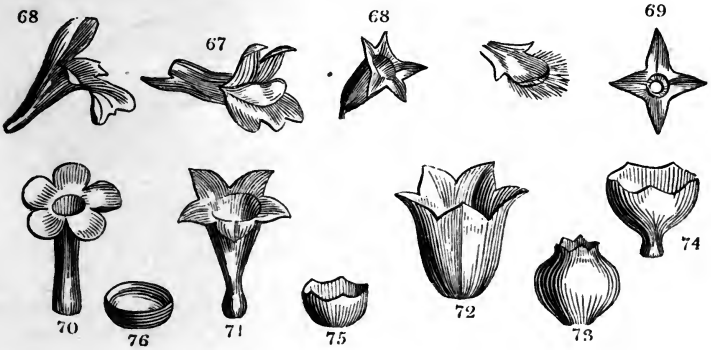
42. Three-edged (*triangularis, triqueter*) ; having three acute angles with concave faces, as the stems of many plants ; generally used as a synonyme of trigonus.
43. Two-edged (*anceps*); compressed, with two sharp edges ; as the stem of Iris.
44. Keeled (*carinatus*); formed in the manner of the keel of a boat ; that is to say, with a sharp projecting ridge, arising from a flat or concave central rib ; as the glumes of Grasses.
45. Channelled (*canaliculatus*); long and concave, so as to resemble a gutter or channel ; as the leaves of Lygeum Spartum, Tradescantia virginica, &c.
46. Boat-shaped (*cymbiformis, navicularis*) ; having the figure of a boat in miniature ; that is to say, concave, tapering to each end, with a keel externally ; as the glumes of Phalaris canariensis.
47. Whip-shaped (*flagelliformis*); long, taper, and supple, like the thong of a whip ; as the stem of Vinca. This is confined to stems and roots.

48. Rope-shaped (*funalis*, † *funiliformis*); formed of coarse fibres resembling cords; as the roots of Pandanus, and other arborescent monocotyledons.
49. Thread-shaped (*filiformis*); slender like a thread; as the filaments of most plants, and the styles of many.
50. Hair-shaped (*capillaris*); the same as filiform, but more delicate, so as to resemble a hair: it is also applied to the fine ramifications of the inflorescence of some plants; as Grasses.
51. Necklace-shaped (*moniliformis*, † *nodosus*, Mirb.); cylindrical or terete, and contracted at regular intervals; as the pods of Sophora japonica, Ornithopus perpusillus, &c, the hairs of Dicksonia arborescens, &c.
52. Worm-shaped (*vermicularis*); thick, and almost cylindrical, but bent in different places; as the roots of Polygonum Bistorta. *Willd.*
53. Knotted (*torulosus*); a cylindrical body, uneven in surface; as the pod of Chelidonium: this is very nearly the same as moniliform.
54. Trumpet-shaped (*tubæformis*, *tubatus*); hollow, and dilated at one extremity, like a trumpet; as the corolla of Caprifolium sempervirens.
55. Horned (*cornutus*, *corniculatus*); terminating in a process resembling a horn; as the fruit of Trapa bicornis. If there are two horns, the word *bicornis* is used; if three, *tricornis*; and so on.
56. Beaked (*proboscideus*); having a hard terminal horn; as Martynia.



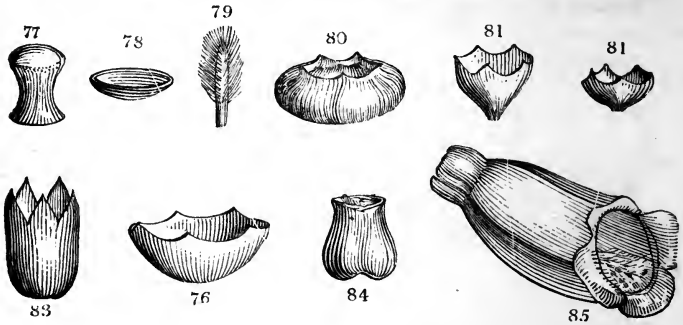
57. Crested (*cristatus*); having an elevated, irregular, or notched ridge, resembling the crest of a helmet. This term is chiefly applied to seeds, and to the appendages of the anthers of some Ericæ; such as E. triflora.
58. Petal-like (*petaloideus*); having the colour and texture of a petal; as one lobe of the calyx of Mussænda, the bracteæ of many plants, the stamen of Canna, the stigmata of Iris.
59. Leaf-like (*foliaceus*, † *foliiformis*, † *phylloideus*); having the texture or form of a leaf; as the lobes of the calyx of Rosa, the apex of the fruit of Fraxinus, the persistent petals of Melanorrhœa.
60. Winged (*alatus*); having a thin broad margin; as the fruit of Paliurus australis, the seed of Malcomia, Bignonia, &c. In composition *pterus* is used; as *dipterus* for two-winged, *tripterus* for three winged, *tetrapterus* for four-winged, &c.; *peripterus* when the wing surrounds any thing; *epipterus* when it terminates.

61. † Mill-sail-shaped († *molendinaceus*); having many wings projecting from a convex surface; as the fruit of some umbelliferous plants, and of Moringa.
62. † Knob-like († *gongylodes*); having an irregular roundish figure.
63. Halved (*dimidiatus*); only half, or partially, formed. A leaf is called dimidiate when one side only is perfect; an anther when one lobe only is perfect; and so on.
64. Fan-shaped (*flabelliformis*); plaited like the rays of a fan; as the leaf of Borassus flabelliformis.
65. Grumous (*grumosus*); in form of little clustered grains; as the root of Nidus-avis, *Mirb.*; rather as the fœcula in the stem of the Sago Palm.
66. † Testicular († *testiculatus*); having the figure of two oblong bodies; as the roots of Orchis mascula.



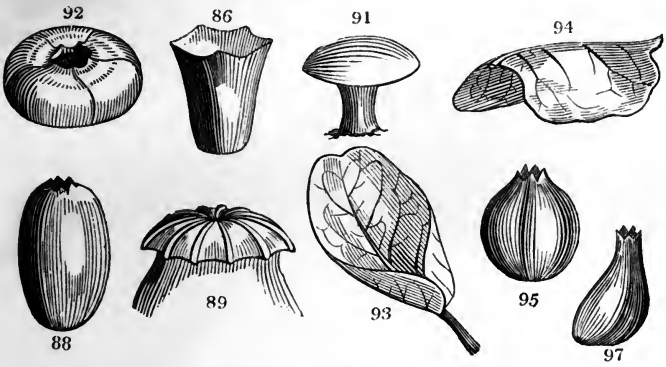
67. Ringent, or personate (*ringens, personatus*); a term applied to a monopetalous corolla, the limb of which is unequally divided; the upper division, or lip, being arched; the lower prominent, and pressed against it, so that when compressed, the whole resembles the mouth of a gaping animal; as the corolla of Antirrhinum.
68. Labiate (*labiatus*); a term applied to a monopetalous calyx or corolla, which is separated into two unequal divisions; the one anterior, and the other posterior, with respect to the axis: hence bilabiate is more commonly used than labiate. Salvia and many other plants afford examples. It is often employed instead of ringent.
69. Wheel-shaped (*rotatus*); a calyx or corolla, or other organ, of which the tube is very short, and the segments spreading; as the corolla of Veronica.
70. Salver-shaped (*hypocrateriformis*); a calyx or corolla, or other organ, of which the tube is long and slender, and the limb flat; as in Phlox.
71. Funnel-shaped (*infundibularis, infundibuliformis*); any organ, in which the tube is obconical, gradually enlarging upwards into the limb, so that the whole resembles a funnel; as the corolla of Nicotiana.
72. Bell-shaped (*campanulatus*, † *campanaceus*, † *campaniformis*); a calyx, corolla, or other organ, in which the tube is inflated, and gradually enlarged into a limb, the base not being conical; as the corolla of Campanula.
73. Pitcher-shaped (*urceolatus*); the same as campanulate, but more contracted at the orifice, with an erect limb; as the corolla of Vaccinium Myrtillus.

74. Cup-shaped (*cyathiformis*); the same as pitcher-shaped, but not contracted at the margin; the whole resembling a drinking-cup; as the limb of the corolla of Symphytum.
75. † Cupola-shaped (†*cupuliformis*); slightly concave, with a nearly entire margin; as the calyx of Citrus, or the cup of an acorn.
76. Kneepan-shaped (*patelliformis*); broad, round, thick; convex on the lower surface, concave on the other: the same as *meniscoideus*, but thicker. The embryo of Flagellaria indica is patelliform.



77. †Pulley-shaped (†*trochlearis*); circular, compressed, contracted in the middle of its circumference, like a pulley; as the embryo of Commelina.
78. Scutelliform (*scutelliformis*); the same as patelliform, but oval; not round, as the embryo of Grasses.
79. †Brush-shaped (†*muscariformis*); formed like a brush or broom; that is to say, furnished with long hairs towards one end of a slender body; as the style and stigma of many Compositæ.
80. Acetabuliform (*acetabuliformis*, †*acetabuleus*); concave, depressed, round, with a border a little turned inwards; as the fruit of some Lichens.
81. †Goblet-shaped (†*crateriformis*); concave, hemispherical, a little contracted at the base; as some Pezizas.
82. †Cotyliform (†*cotyliform*); resembling *rotate*, but with an erect limb.
83. †Poculiform (†*poculiformis*); cup-shaped, with a hemispherical base and an upright limb; nearly the same as campanulate.
84. †Pouch-shaped (†*scrotiformis*); hollow, and resembling a little double bag; as the spur of many Orchises.
85. †Foxglove-shaped (†*digitaliformis*); like campanulate, but longer, and irregular; as the corolla of Digitalis.
86. †Vase-shaped (†*vascularis*); formed like a flower-pot; that is to say, resembling an inverted truncate cone.
87. †Tapeworm-shaped (†*tænianus*); long, cylindrical, contracted in various places, in the manner of the tapeworm.
88. †Sausage-shaped (†*botuliformis*); long, cylindrical, hollow, curved inwards at each end; as the corolla of some Ericas.
89. †Umbrella-shaped (†*umbraculiformis*); resembling an expanded umbrella; that is to say, hemispherical and convex, with rays, or plaits, proceeding from a common centre; as the stigma of Poppy.
90. †Meniscoid (†*meniscoideus*); thin, concavo-convex, and hemispherical, resembling a watch-glass.

91. Mushroom-headed (*fungiformis, fungilliformis*); cylindrical, having a rounded, convex, overhanging extremity; as the embryo of some monocotyledonous plants, as Musa.

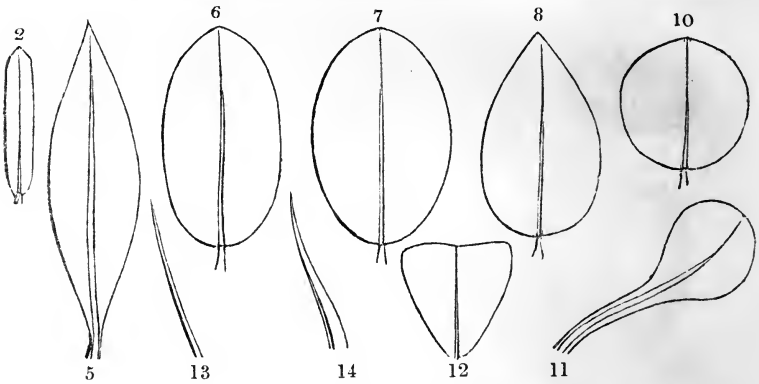


92. †Nave-shaped (†*modioliformis*); hollow, round, depressed, with a very narrow orifice; as the ripe fruit of Gaultheria.
93. Hooded (*cucullatus*); a plane body, the apex or sides of which are curved inwards, so as to resemble the point of a slipper, or a hood; as the leaves of Pelargonium cucullatum, the spatha of Arum, the labellum of Pharus.
94. †Saddle-shaped (*sellæformis*); oblong, with the sides hanging down, like the laps of a saddle; as the labellum of Cattleya Loddigesii.
95. Turgid (*turgidus*); slightly swelling.
96. Bladdery (*inflatus*); thin, membranous, slightly transparent, swelling equally, as if inflated with air; as the calyx of Cucubalus.
97. Bellying (*ventricosus*); swelling unequally on one side; as the corolla of many labiate and personate plants.
98. Regular (*regularis*); in which all the parts are symmetrical. A rotate corolla is regular; the flower of a Cherry is regular.
99. Irregular (*irregularis*); in which symmetry is destroyed by some inequality of parts. A labiate corolla, and the Violet, are irregular.
100. Abnormal (*abnormis*); in which some departure takes place from the ordinary structure of the family or genus to which a given plant belongs. Thus, Nicotiana multivalvis, in which the ovarium has many cells instead of two, is unusual or abnormal.
101. Normal (*normalis*); in which the ordinary structure peculiar to the family or genus of a given plant is in nowise departed from.

B. *With respect to Outline.*

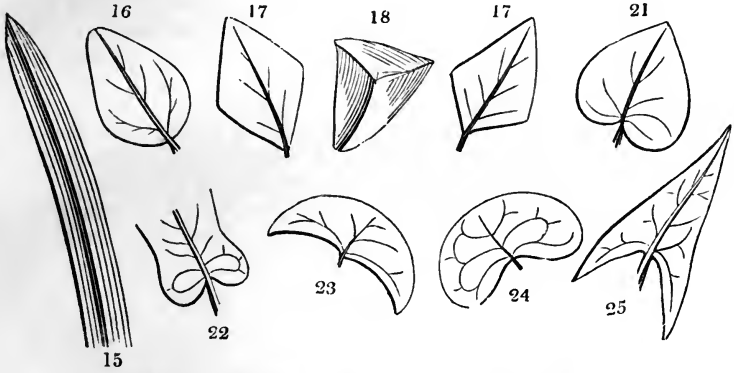
1. Outline (*ambitus, circumscriptio*); the figure represented by the margin.
2. Linear (*linearis*); narrow, short, with the two opposite margins parallel.
3. †Band-shaped (†*fasciarius*); narrow, very long, with the two opposite margins parallel; as the leaves of Zostera marina.
4. Strap-shaped (*ligulatus, loratus*); narrow, moderately long, with the two opposite margins parallel; as the leaves of Amaryllis equestris.

5. Lanceolate (*lanceolatus*); narrowly elliptical, tapering to each end; as the leaf of Plantago lanceolata, Daphne Mezereum, &c.
6. Oblong (*oblongus*); elliptical, obtuse at each end; as the leaf of the Hazel.

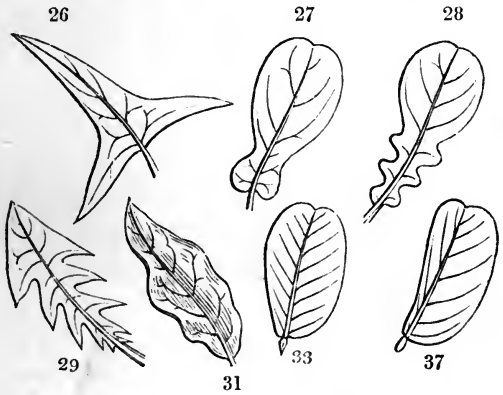


7. Oval (*ovalis, ellipticus*); elliptical, acute at each end; as the leaf of Cornus sanguinea.
8. † Ovate, or egg-shaped (*ovatus*); oblong or elliptical, broadest at the lower end, so as to resemble the longitudinal section of an egg; as the leaf of Stellaria media.
9. Orbicular (*orbicularis*); perfectly circular.
10. Roundish (*rotundus, subrotundus, rotundatus*); orbicular, a little inclining to be oblong; as the leaf of Lysimachia Nummularia, Mentha rotundifolia.
11. Spatulate (*spatulatus*); oblong, with the lower end very much attenuated; so that the whole resembles a spatula; as the leaf of Bellis perennis.
12. Wedge-shaped (*cuneatus, cuneiformis, † cunearius*); inversely triangular, with rounded angles; as the leaf of Saxifraga tridentata.
13. Awl-shaped (*subulatus*); linear, very narrow, tapering to a very fine point from a broadish base; as the leaves of Arenaria tenuifolia, Ulex europæus.
14. Needle-shaped (*acerosus*); linear, rigid, tapering to a fine point from a narrow base; as the leaves of Juniperus communis.
15. Sword-shaped (*ensiformis, gladiatus*); lorate, quite straight, with the point acute; as the leaf of an Iris.
16. † Parabolical (*† parabolicus*); between ovate and elliptical, the apex being obtuse; as the leaf of Amaranthus Blitum.
17. Rhomboid (*rhombeus, rhomboideus*); oval, a little angular in the middle; as the leaf of Hibiscus rhombifolius.
18. Deltoid (*deltoides*); a solid, the transverse section of which has a triangular outline, like the Greek Δ: as the leaf of Mesembryanthemum deltoideum.
19. Triangular (*triangularis*); having the figure of a triangle of any kind; as the leaf of Betula alba.
20. Trapeziform (*trapeziformis, trapezoideus*); having four edges, those which are opposite not being parallel; as the leaf of Adiantum trapeziforme.
21. Heart-shaped (*cordatus, cordiformis*); having two round lobes at the base, the whole resembling the heart in a pack of cards.

22. Eared (*auriculatus*) ; having two small rounded lobes at the base.
23. Crescent-shaped (*lunatus, lunulatus,* † *semilunatus*) ; resembling the figure of the crescent; as the glandular apex of the involucral leaves of many Euphorbias.



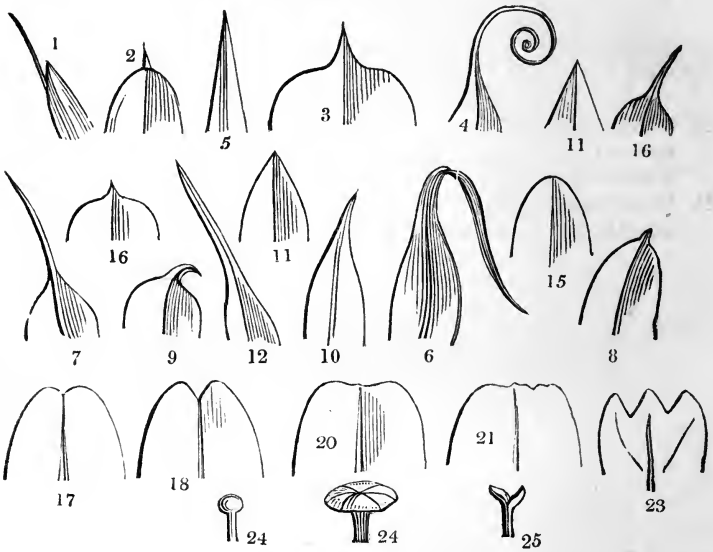
24. Kidney-shaped (*reniformis,* † *renarius*) ; resembling the figure of a kidney ; that is to say, crescent-shaped, with the ends rounded ; as the leaf of Asarum europæum.
25. Arrow-headed (*sagittatus*) ; gradually enlarged at the base into two acute straight lobes, like the head of an arrow ; as the leaf of Rumex Acetosella.



26. Halbert-headed (*hastatus*) ; abruptly enlarged at the base into two acute diverging lobes, like the head of a halbert ; as the leaf of Arum maculatum.
27. Fiddle-shaped (*panduratus, panduriformis*) ; obovate, with a deep recess or sinus on each side ; as the leaves of Rumex pulcher.
28. Lyre-shaped (*lyratus*) ; the same as panduriform, but with several sinuses on each side, which gradually diminish in size to the base ; as the leaf of Geum urbanum, Raphanus Raphanistrum.
29. Runcinate, or hook-backed (*runcinatus*) ; curved in a direction from the apex to the base ; as the leaf of Leontodon Taraxacum.

30. Tapering (*attenuatus*) ; gradually diminishing in breadth.
31. Wavy (*undulatus*) ; having an uneven, alternately convex and concave margin ; as the Holly leaf.
32. Equal (*æqualis*) ; when both sides of a figure are symmetrical ; as the leaf of an Apple.
33. Unequal (*inæqualis*) ; when the two sides of a figure are not symmetrical ; as the leaf of Begonia.
34. Equal-sided (*æquilaterus*) ; the same as equal.
35. Unequal-sided (*inæquilaterus*) ; the same as unequal.
36. Oblique (*obliquus*) ; when the degree of inequality in the two sides is slight.
37. Halved (*dimidiatus*) ; when the degree of inequality is so great that one half of the figure is either wholly or nearly wanting; as in Begonias.

C. *With respect to the Apex, or Point.*

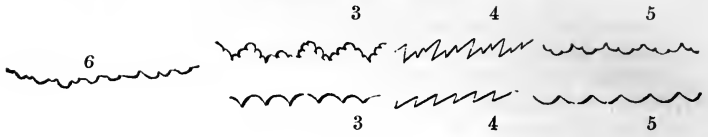


1. Awned (*aristatus*) ; abruptly terminated in a hard, straight, subulate point of various lengths ; as the paleæ of Grasses. The arista is always a continuation of the costa, and sometimes separates below the apex.
2. Mucronate (*mucronatus*) ; abruptly terminated by a hard short point; as the leaf of Statice mucronata.
3. Cuspidate (*cuspidatus*) ; tapering gradually into a rigid point. It is also used sometimes to express abruptly acuminate ; as the leaf of many Rubi.
4. Cirrhous (*cirrhosus, apice circinatus*) ; terminated by a spiral, or flexuose, filiform appendage ; as the leaf of Gloriosa superba.
5. Pungent (*pungens*) ; terminating gradually in a hard sharp point ; as the leaves of Ruscus aculeatus.
6. Bristle-pointed (*setosus*, † *setiger*) ; terminating gradually in a very fine sharp point ; as the leaves of many Mosses.

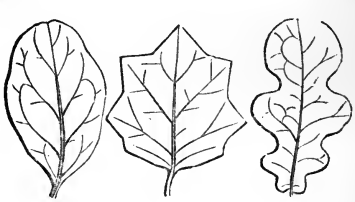
7. Hair-pointed (*piliferus*) ; terminating in a very fine weak point ; as the leaves of many Mosses.
8. Pointleted (*apiculatus*) ; terminating abruptly in a little point ; differing from mucronate in the point being part of the limb, and not of a costa.
9. Hooked (*uncinatus*, † *uncatus*) ; curved suddenly back at the point ; as the leaves of Mesembryanthemum uncinatum.
10. Beaked (*rostratus, rostellatus*) ; terminating gradually in a hard, long, straight point ; as the pod of Radish.
11. Acute, or sharp-pointed (*acutus*) ; terminating at once in a point, not abruptly, but without tapering in any degree ; as any lanceolate leaf.
12. Taper-pointed (*acuminatus*) ; terminating very gradually in a point ; as the leaf of Salix alba.
13. † Acuminose († *acuminosus*) ; terminating gradually in a flat narrow end.
14. Tail-pointed (*caudatus*) ; excessively acuminated, so that the point is long and weak, like the tail of some animal ; as the calyx of Aristolochia trilobata, the petals of Brassia caudata.
15. Blunt (*obtusus*) ; terminating gradually in a rounded end.
16. Blunt with a point (*obtusus cum acumine*) ; terminating abruptly in a round end, the middle of which is suddenly lengthened into a point ; as the leaf of many Rubi.
17. Retuse (*retusus*) ; terminating in a round end, the centre of which is depressed ; as the leaf of Vaccinium Vitis Idæa.
18. Emarginate (*emarginatus*) ; having a notch at the end, as if a piece had been taken out ; as the leaf of Buxus sempervirens.
19. † *Accisus ;* when the end has an acute sinus between two rounded angles.
20. Truncate (*truncatus*) ; terminating very abruptly, as if a piece had been cut off ; as the leaf of Liriodendron tulipifera.
21. Bitten (*præmorsus*, † *succisus*) ; the same as truncate, except that the termination is ragged and irregular, as if bitten off : the term is generally applied to roots ; the leaf of Caryota urens is another instance.
22. † Dædaleous († *dædaleus*) ; when the point has a large circuit, but is truncated and rugged. *W.*
23. Trident-pointed (*tridentatus*) ; when the point is truncated, and has three indentations (*W.*) ; as Saxifraga tridentata, Potentilla tridentata.
24. Headed (*capitatus*) ; suddenly much thicker at the point than in any other part ; a term confined to cylindrical or terete bodies ; as glandular hairs, &c.
25. Lamellar (*lamellatus, lamellosus*) ; having two little plates at the point ; as the style of many plants.
26. † Blunt († *hebetatus*, De Cand.) ; having a soft obtuse termination.
27. Pointless (*muticus*). This term is employed only in contradistinction to some other that indicates being pointed ; thus, if in contrasting two things, one were said to be mucronate, the other, if it had not a mucro, would be called pointless : and the same term would be equally employed in contrast with cuspidate or aristate, or any such. It is also used absolutely.

2. Of Division.

A. *With respect to the Margin.*



1. Entire (*integer*). Properly speaking, this means having no kind of marginal division ; but sometimes it has been used to indicate not pinnatifid, and also nearly destitute of marginal division.
2. Quite entire (*integerrimus*) ; perfectly free from division of the margin.
3. Crenated (*crenatus*); having convex teeth. When these teeth are themselves crenated, we say *bicrenate.*
4. Sawed (*serratus*) ; having sharp straight-edged teeth pointing to the apex. When these teeth are themselves serrate, we say *biserrate,* or *duplicato-serrate.*
5. Toothed (*dentatus*); having sharp teeth with concave edges. When these teeth are themselves toothed, we say *duplicato-dentate,* or doubly toothed, but not *bidentate,* which means two-toothed.
6. Gnawed (*erosus*); having the margin irregularly toothed, as if bitten off.
7. Curled (*crispus*) ; having the margin excessively irregularly divided and twisted ; as in many varieties of the Garden Endive, Mentha crispa.

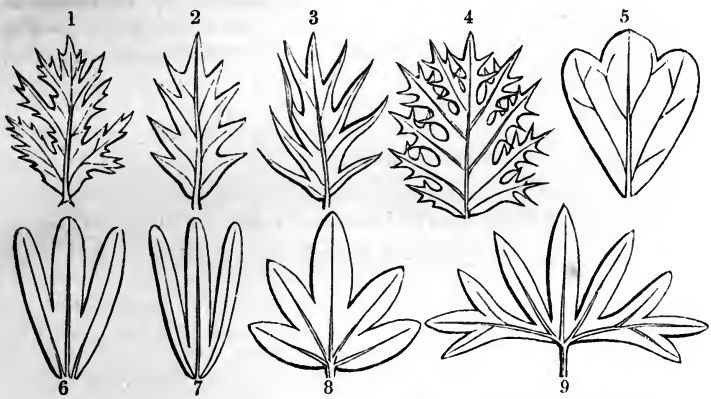


8. Repand (*repandus,* † *sinuolatus*); having an uneven slightly sinuous margin; as the leaf of Solanum nigrum.
9. Angular (*angulatus, angulosus*) ; having several salient angles on the margin ; as the leaf of Datura Stramonium.
10. Sinuate (*sinuatus*) ; having the margin uneven, alternately with deep concavities and convexities ; as the leaf of Quercus Robur.

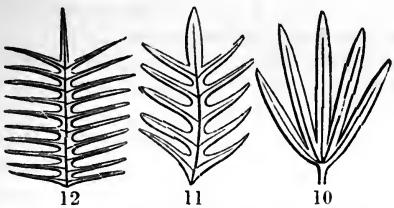
B. *With respect to Incision.*

1. Torn (*lacerus*); irregularly divided by deep incisions.
2. Cut (*incisus*) ; regularly divided by deep incisions.
3. Slashed (*laciniatus*); divided by deep, taper-pointed, cut incisions.
4. Squarrose-slashed (*squarroso-laciniatus*) ; slashed with minor divisions at right angles with the others.

5. Lobed (*lobatus*) ; partly divided into a determinate number of segments. We say *bilobus*, two-lobed, as in the leaf of Bauhinia porrecta ; *trilobus*, three-lobed, as in the leaf of Anemone Hepatica ; and so on.



6. Split (*fissus*) ; divided nearly to the base, into a determinate number of segments. We say *bifidus*, split in two ; *trifidus*, in three ; as in the leaf of Teucrium Chamæpitys ; and so on. When the segments are very numerous, *multifidus* is used.
7. Parted (*partitus*) ; divided into a determinate number of segments, which extend nearly to the base of the part to which they belong. We say *bipartitus*, parted in two ; *tripartitus*, in three ; and so on.
8. Palmate (*palmatus*) ; having five lobes, the midribs of which meet in a common point, so that the whole bears some resemblance to a human hand; as the leaf of Passiflora cærulea.
9. Pedate (*pedatus*); the same as palmate, except that the two lateral lobes are themselves divided into smaller segments, the midribs of which do not directly run into the same point as the rest ; as the leaf of Arum Dracunculus, Helleborus niger, &c.



10. Fingered (*digitatus*) ; the same as palmate, but the segments less spreading, and narrower.
11. Pinnatifid (*pinnatifidus, pinnatipartitus, pinnatiscissus*) ; divided almost to the axis into lateral segments, something in the way of the side divisions of a feather ; as Polypodium vulgare. M. De Candolle distinguishes several modifications of pinnatifidus :—1. *Pinnatifidus*, when the lobes are divided down to half the breadth of the leaf : 2. *pinnatipartitus*, when the lobes

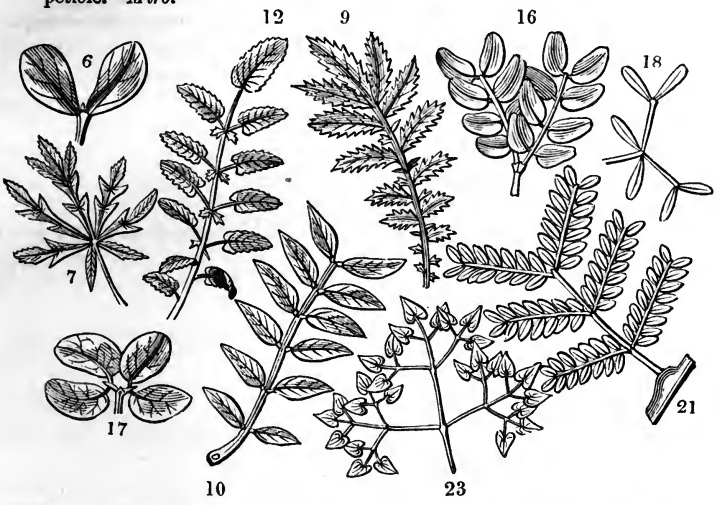
pass beyond the middle, and the parenchyma is not interrupted: 3. *pinnatisectus*, when the lobes are divided down to the midrib, and the parenchyma is interrupted: 4. *pinnatilobatus*, when the lobes are divided to an uncertain depth; *lyrate* and the like belong to this modification. He has similar variations of palmatus and pedatus; viz. *palmatifidus, palmatipartitus, palmatisectus, palmatilobatus;* and *pedatifidus, pedatipartitus, pedatisectus,* and *pedatilobatus.*

12. Comb-shaped (*pectinatus*); the same as pinnatifid; but the segments very numerous, close, and narrow, like the teeth of a comb; as the leaf of Lavandula dentata, all Mertensias.

C. *With respect to Composition or Ramification.*

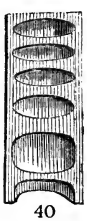
1. Simple (*simplex*); scarcely divided or branched at all.
2. Quite simple (*simplicissimus*); not divided or branched at all.
3. Compound (*compositus*); having various divisions or ramifications. As compared with the two following, it applies to cases of leaves in which the petiole is not divided; as in the Orange.
4. Decompound (*decompositus*); having various compound divisions or ramifications. In leaves it is applied to those the petiole of which bears secondary petioles; as in the leaf of Mimosa purpurea.
5. Supradecompound (*supradecompositus*); having various decompound divisions or ramifications. In leaves it is applied to such as have the primary petiole divided into secondary ones, and the secondary into a third set; as in the leaf of Daucus Carota.
6. † Bifoliolate († *bifoliolatus, binatus*); when in leaves the common petiole is terminated by two leaflets growing from the same point; as in Zygophyllum Fabago. This term has the same application as *unijugus* and *conjugatus.* We say *trifoliolate,* or *ternate,* when the petiole bears three leaflets from the same point; as in Menyanthes trifoliata: † *quadrifoliolate,* if there are four from the same point; as in Marsilea quadrifolia: and *quinquefoliolate,* or *quinate,* if there are five from the same point; as in Potentilla reptans.
7. † Vertebrate († *vertebratus*); when the leaf is contracted at intervals, there being an articulation at each contraction; as in Cussonia spicata. *Mirb.*
8. Pinnate (*pinnatus*); when simple leaflets are arranged on each side a common petiole; as in Polypodium vulgare.
9. Pinnate with an odd one (*impari-pinnatus*); when the petiole is terminated by a single leaflet or tendril; as in Pyrus aucuparia. If there is a tendril, as in the Pea, it is called *cirrhose.*
10. Equally pinnate (*pari-pinnatus, abruptè pinnatus*); when the petiole is terminated by neither leaflet nor tendril; as Orobus tuberosus.
11. † Alternately pinnate († *alternatim pinnatus*); when the leaflets are alternate upon a common petiole; as in Potentilla rupestris. *Mirb.*
12. Interruptedly pinnate (*interruptè pinnatus*); when the leaflets are alternately small and large; as in the Potato.
13. † Decreasingly pinnate († *decrescentè pinnatus*); when the leaflets diminish insensibly in size, from the base of the leaf to its apex, as in Vicia sepium.
14. † Decursively pinnate († *decursivè pinnatus*); when the petiole is winged by the elongation of the base of the leaflets; as in Melianthus. *Mirb.* This is hardly different from pinnatifid.

15. Digitato-pinnate (*digitato-pinnatus*) ; when the secondary petioles, on the sides of which the leaflets are attached, part from the summit of a common petiole. *Mirb.*



16. Twin digitato-pinnate (*bidigitato-pinnatus, biconjugato-pinnatus*) ; the secondary petioles, on the sides of which the leaflets are arranged, proceed in twos from the summit of a common petiole ; as in Mimosa purpurea.
17. Bigeminate (*bigeminatus, biconjugatus*) ; when each of two secondary petioles bears a pair of leaflets ; as in Mimosa unguis Cati. *Mirb.*
18. Tergeminate (*tergeminus*) ; when each of two secondary petioles bears towards its summit one pair of leaflets, and the common petiole a third pair at the origin of the secondary petioles ; as in Mimosa tergemina.
19. Thrice digitato-pinnate († *tridigitato-pinnatus, ternato-pinnatus*) ; when the secondary petioles, on the sides of which the leaflets are attached, proceed in threes from the summit of a common petiole ; as in Hoffmannseggia.
20. † *Quadridigitato-pinnatus,* as in Mimosa pudica, and † *Multidigitato-pinnatus,* are rarely used, but are obvious modifications of the last.
21. Bipinnate (*bipinnatus,* † *duplicato-pinnatus*) ; when the leaflets of a pinnate leaf become themselves pinnate ; as in Mimosa Julibrissin.
22. Biternate (*biternatus,* † *duplicato-ternatus*) ; when three secondary petioles proceed from the common petiole, and each bears three leaflets ; as in Fumaria bulbosa, Imperatoria Ostruthium, &c. *Mirb.*
23. Triternate (*triternatus*) ; when the common petiole divides into three secondary petioles, which are each subdivided into three tertiary petioles, each of which bears three leaflets ; as the leaf of Epimedium.
24. Tripinnate (*tripinnatus*) ; when the leaflets of a bipinnate leaf become themselves pinnate ; as in Thalictrum minus, or Œnanthe Phellandrium.
25. Paired (*conjugatus, unijugus,* † *unijugatus*) ; when the petiole of a pinnated leaf bears one pair of leaflets ; as Zygophyllum Fabago. *Bijugus* is when it bears two pairs ; as in Mimosa fagifolia : *trijugus, quadrijugus, quinquejugus,* &c., are also employed when required. *Multijugus* is used when the number of pairs becomes very considerable ; as in Orobus sylvaticus.

26. Branched (*ramosus*) ; divided into many branches : if the divisions are small, we say *ramulosus.*
27. Somewhat branched (*subramosus*) ; having a slight tendency to branch.
28. Excurrent (*excurrens*) ; in which the axis remains always in the centre, all the other parts being regularly disposed round it ; as the stem of Abies.
29. Much-branched (*ramosissimus*) ; branched in a great degree.
30. † Disappearing († *deliquescens*) ; branched, but so divided that the principal axis is lost trace of in the ramifications ; as the head of an oak tree.
31. Dichotomous (*dichotomus*) ; having the divisions always in pairs ; as the branches and inflorescence of Stellaria holostea : if they are in threes, we say *trichotomus ;* as the stem of Mirabilis Jalapa.
32. Twin (*didymus*) ; growing in pairs, or divided into two equal parts ; as the fruit of Galium.
33. Forked (*furcatus*); having long terminal lobes, like the prongs of a fork ; as Ophioglossum pendulum.
34. Stellate (*stellatus*); divided into segments, radiating from a common centre ; as the hairs of most malvaceous plants.
35. Jointed (*articulatus*) ; falling in pieces at the joints, or separating readily at the joints ; as the pods of Ornithopus, the leaflets of Guilandina Bonduc : it is also applied to bodies having the appearance of being jointed ; as the stem and leaves of Juncus articulatus.
36. Granular (*granulatus*); divided into little knobs or knots ; as the rhizomes of Saxifraga granulata.
37. † Byssaceous († *byssaceus*) ; divided into very fine pieces, like wool ; as the roots of some Agarics.
38. † Tree-like († *dendroides*); divided at the top into a number of fine ramifications, so as to resemble the head of a tree ; as Lycopodium dendroideum.
39. Brush-shaped († *aspergilliformis*); divided into several fine ramifications, so as to resemble the brush (*aspergillus*) used for sprinkling holy water in the ceremonies of the Catholic Church ; as the stigmas of grasses.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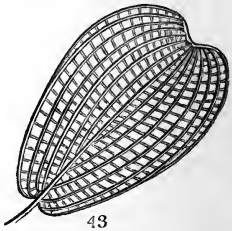
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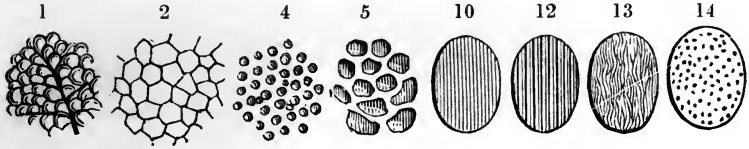
40. Partitioned (*loculosus,* † *septatus,* † *phragmiger*); divided by internal partitions into cells ; as the pith of the plant that produces the Chinese rice-paper. This is never applied to fruits.
41. Anastomosing (*anastomozans*); the ramifications of anything which are united at the points where they come in contact are said to anastomose. The term is confined to veins.
42. Ruminate (*ruminatus*); when a hard body is pierced in various directions by narrow cavities filled with dry cellular matter; as the albumen of the nutmeg and the Anona.
43. † Cancellate († *cancellatus*) ; when the parenchyma is wholly absent, and

the veins alone remain, anastomosing and forming a kind of network; as the leaves of Hydrogeton fenestralis.

44. Perforated (*pertusus*); when irregular spaces are left open in the surface of anything, so that it is pierced with holes; as the leaves of Dracontium pertusum.

3. Of Surface.

A. *With respect to Marking or Evenness.*

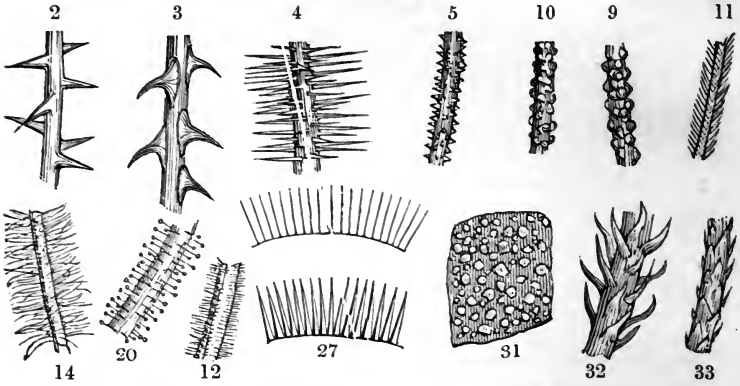


1. Rugose (*rugosus*); covered with reticulated lines, the spaces between which are convex; as the leaves of Sage.
2. Netted (*reticulatus*); covered with reticulated lines which project a little; as the under surface of the leaves of most Melastomas, the seeds of Geranium rotundifolium.
3. † Half-netted († *semireticulatus*); when, of several layers of anything, the outer one only is reticulated; as in the roots of Gladiolus communis.
4. Pitted (*scrobiculatus*); having numerous small shallow depressions or excavations; as the seed of Datisca cannabina, Passiflora, &c.
5. Lacunose (*lacunosus*); having numerous large deep excavations.
6. Honeycombed (*favosus, alveolatus*); excavated in the manner of a section of honeycomb; as the receptacle of many Composites, the seeds of Papaver.
7. † Areolate († *areolatus*); divided into a number of irregular squares or angular spaces.
8. Scarred (*cicatrisatus*); marked by the scars left by bodies that have fallen off; the stem, for instance, is scarred by the leaves that have fallen.
9. Ringed (*annulatus*); surrounded by elevated or depressed bands; as the roots of some plants, the cupulæ of several Oaks, &c.
10. Striated (*striatus*); marked by longitudinal lines; as the petals of Geranium striatum.
11. Lined (*lineatus*); the same as striatus.
12. Furrowed (*sulcatus*); marked by longitudinal channels; as the stem of Conium, of the Parsnep, of Spiræa Ulmaria, &c.
13. † Aciculated (*aciculatus*); marked with very fine irregular streaks, as if produced by the point of a needle.
14. Dotted (*punctatus*); covered by minute impressions, as if made by the point of a pin; as the seed of Anagallis arvensis, Geranium pratense.
15. Even (*æquatus*); the reverse of anything expressive of inequality of surface.

B. *With respect to Appendages or superficial Processes.*

1. Unarmed (*inermis*); destitute of any kind of spines or prickles.
2. Spiny (*spinosus*); furnished with spines; as the branches of Whitethorn.
3. Prickly (*aculeatus*); furnished with prickles; as the stem of a Rose.

4. Bristly (*echinatus*) ; furnished with numerous rigid hairs, or straight prickles ; as the fruit of Castanea vesca.



5. Muricated (*muricatus*) ; furnished with numerous short hard excrescences ; as the fruit of the Arbutus Unedo.
6. Spiculate († *spiculatus*) ; covered with fine, fleshy, erect points.
7. Rough (*scaber, asper, exasperatus*) ; covered with hard, short, rigid points ; as the leaves of Borago officinalis.
8. Roughish (*scabridus*) ; slightly covered with short hardish points ; as the leaf of Thymus Acinos.
9. Tubercled (*tuberculatus, verrucosus*) ; covered with little excrescences or warts ; as the stem of Cotyledon tuberculata, the leaf of Aloe margaritifera.
10. Pimpled (*papillosus*, † *papulosus*) ; covered with minute tubercles or excrescences, of uneven size, and rather soft ; as the leaves of Mesembryanthemum crystallinum.
11. Hairy (*pilosus*) ; covered with short, weak, thin hairs ; as the leaf of Prunella vulgaris, Daucus Carota.
12. Downy (*pubens, pubescens*) ; covered with very short, weak, dense hairs ; as the leaves of Cynoglossum officinale, Lonicera Xylosteum, &c. Pubescens is most commonly employed in Botany, but pubens is more classical.
13. Hoary (*incanus*) ; covered with very short dense hairs, placed so closely as to give an appearance of whiteness to the surface from which they grow ; as the leaf of Mathiola incana.
14. Shaggy (*hirtus, villosus*) ; covered with long weak hairs ; as Epilobium hirsutum.
15. Tomentose (*tomentosus*) ; covered with dense, rather rigid, short hairs, so as to be sensibly perceptible to the touch ; as Onopordum Acanthium, Lavatera arborea, &c.
16. Velvety (*velutinus*) ; the same as the last, but more dense, so that the surface resembles that of velvet ; as Cotyledon coccineus.
17. Woolly (*lanatus*) ; covered with long, dense, curled, and matted hairs, resembling wool ; as Verbascum Thapsus, Stachys germanica.
18. Hispid (*hispidus*) ; covered with long rigid hairs ; as the stem of Borage.
19. Floccose (*floccosus*) ; covered with dense hairs, which fall away in little tufts ; as Verbascum floccosum, and pulverulentum.

20. Glandular (*glandulosus*) ; covered with hairs bearing glands upon their tips ; as the fruit of Roses, the pods of Adenocarpus.
21. Bearded (*barbatus, crinitus*) ; having tufts of long weak hairs growing from different parts of the surface ; as the leaves of Mesembryanthemum barbatum. It is also applied to bodies bearing very long weak hairs in solitary tufts ; as the filaments of Anthericum, the pods of Adesmia.
22. Strigose (*strigosus*); covered with sharp, appressed, rigid hairs. *W.* Linnæus considers this word synonymous with hispid.
23. Silky (*sericeus*) ; covered with very fine close-pressed hairs, silky to the touch ; as the leaves of Protea argentea, Alchemilla alpina, &c.
24. † Peronate (*peronatus*) ; laid thickly over with a woolly substance, ending in a sort of meal. *W.* This term is only applied to the stipes of Fungi.
25. Cobwebbed (*arachnoides*) ; covered with loose, white, entangled, thin hairs ; resembling the web of a spider ; as Calceolaria arachnoidea.
26. Ciliated (*ciliatus*) ; having fine hairs, resembling the eyelash, at the margin; as the leaves of Luzula pilosa, Erica Tetralix, &c.
27. Fringed (*fimbriatus*); having the margin bordered by long filiform processes thicker than hairs ; as the petals of Cucubalus fimbriatus.
28. Feathery (*plumosus*) ; consisting of long hairs, which are themselves hairy ; as the pappus of Leontodon Taraxacum, the beard of Stipa pennata.
29. Stinging (*urens*) ; covered with rigid, sharp-pointed, bristly hairs, which emit an irritating fluid when touched ; as the leaves of the Urtica urens.
30. Mealy (*farinosus*) ; covered with a sort of white scurfy substance ; as the leaves of Primula farinosa, and of some Poplars.
31. Leprous (*lepidotus, leprosus*) ; covered with minute peltate scales ; as the foliage of Elæagnus.
32. Ramentaceous (*ramentaceus*) ; covered with weak, shrivelled, brown, scale-like processes ; as the stems of many Ferns.
33. Scaly (*squamosus*) ; covered with minute scales, fixed by one end ; as the young shoots of the Pine tribe.
34. Chaffy (*paleaceus*) ; covered with small, weak, erect, membranous scales, resembling the paleæ of Grasses ; as the receptacle of many Composites.

C. *With respect to Polish or Texture.*

1. Shining (*nitidus*) ; having a smooth, even, polished surface.
2. Smooth (*glaber, lævis*) ; being free from asperities or hairs, or unevenness.
3. Polished (*lævigatus, †politus*); having the appearance of a polished substance ; as the testa of Abrus precatorius, and many seeds.
4. † Glittering (†*splendens*); the same as polished, but when the lustre is a little broken, from slight irregularity of surface.
5. Naked (*nudus, denudatus*) ; the reverse of hairy, downy, or any similar term : it is not materially different from glaber.
6. Opaque (*opacus*); the reverse of shining, dull.
7. Viscid (*viscidus, glutinosus*); covered with a glutinous exudation.
8. Mucous, or slimy (*mucosus*); covered with a slimy secretion ; or with a coat that is readily soluble in water, and becomes slimy.
9. † Greasy (†*unctuosus*); having a surface which, though not greasy, feels so.
10. Dewy (*roridus*); covered with little transparent elevations of the parenchyma, which have the appearance of fine drops of dew.

11. † Dusty († *lentiginosus*); covered with minute dots or specks, as if dusted; the calyx and corolla of Ardisia lentiginosa.
12. Frosted (*pruinosus*); nearly the same as roridus, but applied to surfaces in which the dewy appearance is more opaque, as if the drops were congealed; as the surface of the leaves of Rosa pruinosa and glutinosa.
13. Powdery (*pulverulentus*); covered with a fine bloom or powdery matter; as the leaves of Primula farinosa.
14. Glaucous (*glaucus*); covered with a fine bloom of the colour of a Cabbage.
15. Cæsious (*cæsius*); like glaucous, but greener.
16. Whitened (*dealbatus*); covered with a very opaque white powder; as the leaves of many Cotyledons.

4. Of Texture or Substance.

1. Membranaceous (*membranaceus*); thin and semitransparent, like a fine membrane; as the leaves of Mosses.
2. Papery (*papyraceus, chartaceus*); having the consistence of writing-paper, and quite opaque; as most leaves.
3. Leathery (*coriaceus,* † *alutaceus*); having the consistence of leather; as the leaves of Pothos acaulis, Prunus Laurocerasus, and others.
4. Crustaceous (*crustaceus*); hard, thin, and brittle; as the testa of Asparagus, or of Passiflora.
5. Cartilaginous (*cartilagineus*); hard and tough; as the seed of an apple.
6. Loose (*laxus*); of a soft cellular texture, as the pith of most plants. The name is derived from the parts of the substance appearing as if not in a state of cohesion.
7. Scarious (*scariosus*); having a thin, dry, shrivelled appearance; as the involucral leaves of many species of Centaurea.
8. Corky (*suberosus*); having the texture of the substance called cork; as the bark of Ulmus suberosa.
9. Coated (*corticatus*); harder externally than internally.
10. Spongy (*spongiosus*); having the texture of a sponge; that is to say, very cellular, with the cellules filled with air; as the coats of many seeds.
11. Horny (*corneus*); hard, and very close in texture, but capable of being cut without difficulty, the parts cut off not being brittle; as the albumen of many plants.
12. Oleaginous (*oleaginosus*); fleshy in substance, but filled with oil.
13. Bony (*osseus*); hard, and very close in texture, not cut without difficulty, the parts cut off being brittle; as the stone of a peach.
14. Fleshy (*carnosus*); firm, juicy, easily cut.
15. Waxy (*ceraceus, cereus*); having the texture and colour of new wax; as the pollen masses of some Orchids.
16. Woody (*lignosus, ligneus*); having the texture of wood.
17. Thick (*crassus*); something more thick than usual. Leaves, for instance, are generally papery in texture; the leaves of cotyledons, which are much more fleshy, are called *thick*.
18. Succulent (*succulentus*); very cellular and juicy; as the stems of Stapelias.
19. Gelatinous (*gelatinosus*); having the texture and appearance of jelly; as Ulvas, and similar things.
20. Fibrous (*fibrosus*); containing a great proportion of loose woody fibre; as the rind of a cocoa-nut.

21. † Medullary, or pithy (†*medullosus*); filled with spongy pith.
22. Mealy (*farinaceus*); having the texture of flour in a mass; as the albumen of Wheat.
23. Tartareous (*tartareus*); having a rough crumbling surface; like the thallus of some Lichens.
24. Berried (*baccatus*); having a juicy succulent texture.
25. Herbaceous (*herbaceus*); thin, green, and cellular; as the tissue of membranous leaves.

5. Of Size.

Most of the terms which relate to this quality are the same as those in common use; and, being employed in precisely the same sense, do not need explanation. But there are a few which have a particular meaning attached to them, and are not much known in common language. These are,—

1. Dwarf (*nanus, pumilus, pygmæus*); small, short, dense, as compared with other species of the same genus, or family. Thus, Myosotis nana is not more than half an inch high; while the other species are much taller.
2. Very small (*pusillus, perpusillus*); the same as the last, except that a general reduction of size is understood, as well as dwarfishness.
3. Low (*humilis*); when the stature of a plant is not particularly small, but much smaller than of other kindred species. Thus, a tree twenty feet high may be *low*, if the other species of its genus are forty or fifty feet high.
4. Depressed (*depressus*); broad and dwarf, as if, instead of growing perpendicularly, the growth had taken place horizontally; as some species of Cochlearia, Coronopus Ruellii, and many others.
5. Little (*exiguus*); this is generally used in opposition to large, and means small in all parts, but well proportioned.
6. Tall (*elatus, procerus*); this is said of plants which are taller than their parts would have led one to expect.
7. Lofty (*exaltatus*); the same as the last, but in a greater degree.
8. Gigantic (*giganteus*); tall, but stout and well proportioned.

To this class must also be referred words or syllables expressing the proportion which one part bears to another.

1. *Isos*, or equal, placed before the name of an organ, indicates that it is equal in number to that of some other understood: thus, *isostemonous* is said of plants the stamens of which are equal in number to the petals. *De Cand.*
2. *Anisos*, or unequal, is the reverse of the latter: thus, *anisostemonous* would be said when the stamens are not equal in number to the petals.
3. † *Meios*, or less, prefixed to the name of an organ, indicates that it is something less than some other organ understood: thus, † *meiostemonous* would be said of a plant the stamens of which are fewer than the petals.
4. *Duplo, triplo*, &c., or double, triple, &c., signify that the organs to the name of which they are prefixed are twice or thrice as numerous or large as those of some other.

The terms which express measures of length are the following:—

1. A hair's breadth (*capillus*, its adjective *capillaris*); the twelfth of a line.
2. A line (*linea*, adj. *linealis*); the twelfth part of an inch.
3. A nail (*unguis*); half an inch, or the length of the nail of the little finger.

4. An inch (*pollex, uncia;* adj. *pollicaris, uncialis*); the length of the first joint of the thumb.
5. A small span (*spithama*, adj. *spithamæus*); seven inches, or the space between the thumb and the fore-finger separated as widely as possible.
6. A palm (*palmus*, adj. *palmaris*); three inches, or the breadth of the four fingers of the hand.
7. A span (*dodrans*, adj. *dodrantalis*); nine inches, or the space between the the thumb and the little finger separated as widely as possible.
8. A foot (*pes*, adj. *pedalis*); twelve inches, or the length of a tall man's foot.
9. A cubit (*cubitus*, adj. *cubitalis*); seventeen inches, or the distance between the elbow and the tip of the fingers.
10. An ell (*ulna, brachium;* adj. *ulnaris, brachialis*); twenty-four inches, or the length of the arm.
11. A toise (*orgya*, adj. *orgyalis*); six feet, or the ordinary height of man.
12. *Sesqui.* This term, prefixed to the Latin name of a measure, shows that such measure exceeds its due length by one half: thus, *sesquipedalis* means a foot and a half.
13. † A millimetre=$\frac{443}{1000}$ of a French line.
14. † A centimetre=4 French lines and $\frac{432}{1000}$.
15. † A decimetre=3 French inches, eight lines, $\frac{329}{1000}$.
16. † A metre=3 feet, 11 lines, $\frac{296}{1000}$ French; or, 39·371 inches English.

Obs. The last four terms are French measures, which are rarely used, and for which no equivalent Latin terms are employed.

6. Of Duration.

The terms in ordinary use to express the absolute period of duration of a plant are sufficiently precise for common purposes, but are too inaccurate to be longer admitted within the pale of science. I have, therefore, adopted the phraseology of De Candolle, as far as relates to words expressive of the actual term of vegetable existence.

1. *Monocarpous;* bearing fruit but once, and dying after fructification; as Wheat. Some live but one year, and are called annuals: the term of the existence of others is prolonged to two years; these are biennials: others live for many years before they flower, but die immediately afterwards; as the Agave americana. The latter have no English name. Annuals are indicated by the signs ☉ or ①; biennials by ♂ or ②; and the others by ♾.
2. *Polycarpous* (better *syclinocarpous*); having the power of bearing fruit many times without perishing. Of this there are two forms:—
   A. *Caulocarpous*, or those whose stem endures many years, constantly bearing flowers and fruits; as trees and shrubs. The sign of these is ♄.
   B. *Rhizocarpous*, or those whose root endures many years, but whose stems perish annually; as herbaceous plants. The sign of these is ♃.
3. *Hysteranthous;* when leaves appear after flowers; as the Almond, Tussilago fragrans, &c.
4. † *Synanthous;* when flowers and leaves appear at the same time.
5. † *Proteranthous;* when the leaves appear before the flowers.
6. *Double-bearing* (*biferus*); when any thing is produced twice in one season.

7. *Often-bearing* (+ *multiferus*) ; when any thing is produced several times in one season.

Besides the foregoing, those that follow require explanation :—

1. Of an hour (*horarius*) ; which endures for an hour or two only ; as the flowers of Talinum, Cistus, &c.
2. Of a day (*ephemerus*, + *diurnus*) ; which endures but a day, as the flower of Tigridia. *Biduus* is said of things that endure two days ; and *triduus*, three days.
3. Of a night (*nocturnus*) ; which appears during the night, and perishes before morning ; as the flowers of the night-blooming Cereus.
4. Of a month (*menstrualis*, + *menstruus*) ; which last for a month. *Bimestris* is said of things that exist for two months ; *trimestris*, for three months.
5. Yearly (*annotinus*) ; that which has the growth of a year. Thus *rami annotini* are branches a year old.
6. Of the same year (*hornus*), is said of any thing the produce of the year. Thus *rami horni* would be branches not a year old.
7. Deciduous (*deciduus*) ; finally falling off ; as the calyx and corolla of Cruciferæ.
8. Caducous (*caducus*) ; falling off very early ; as the calyx of the Poppy.
9. Persistent (*persistens*, + *restans*, Linn.) ; not falling off, but remaining green until the part which bears it is wholly matured ; as the leaves of evergreen plants, the calyx of Labiatæ and others.
10. Withering, or fading (*marcescens*) ; not falling off until the part which bears it is perfected, but withering long before that time ; as the flowers of Orobanche.
11. Fugacious (*fugax*) ; falling off, or perishing very rapidly ; as many minute Fungi, the petals of Cistus, &c.
12. Permanent (*perennans*) ; not different from persistent : it is generally applied to leaves.
13. Perennial (*perennis*) ; lasting for several years.

7. Of Colour.

The most useful books to consult for the distinctions of colours are Syme's *Book of Colours*, and the chromatic scale in the Duke of Bedford's publication upon Ericas.

The best practical arrangement of colours, as applied to plants, is that of Bischoff, in his excellent *Terminology* ; what follows is chiefly taken from that work.

There are eight principal colours, under which all the others may be arranged; viz. white, grey, black, brown, yellow, green, blue, and red.

I. White (*albus ;* in words compounded of Greek, *leuco-*).

1. Snow-white (*niveus*) ; as the purest white ; Camellia japonica.
2. Pure white (*candidus ;* in Greek composition, *argo-*) ; very pure, but not so clear as the last ; Lilium candidum.
3. Ivory-white (cream-colour ; *eburneus*, *eborinus*) ; white verging to yellow, with a little lustre ; Convallaria majalis.

4. Milk-white (*lacteus;* in words compounded of Greek, *galacto-*); dull white verging to blue.
5. Chalk-white (*cretaceus, calcareus, gypseus*); very dull white, with a little touch of grey.
6. Silvery (*argenteus*); a little changing to bluish grey, with something of a metallic lustre.
7. Whitish (*albidus*); any kind of white a little soiled.
8. Turning white (*albescens*); changing to a whitish cast from some other colour.
9. Whitened (*dealbatus*); slightly covered with white upon a darker ground.

II. Grey.

10. Ash-grey (*cinereus;* in words compounded of Greek, *tephro-* and *spodo-*); a mixture of pure white and pure black, so as to form an intermediate tint.
11. Ash-greyish (*cineraceus*); the same, but whiter.
12. Pearl-grey (*griseus*); pure grey, a little verging to blue.
13. Slate-grey (*schistaceus*); grey, bordering on blue.
14. Lead-coloured (*plumbeus*); the same, with a little metallic lustre.
15. Smoky (*fumeus, fumosus*); grey, changing to brown.
16. Mouse-coloured (*murinus*); grey, with a touch of red.
17. Hoary (*canus*, or *incanus*); a greyish whiteness, caused by hairs overlying a green surface.
18. Rather hoary (*canescens*); a variety of the last.

III. Black.

19. Pure black (*ater;* in Greek composition, *mela-* or *melano-*), is black without the mixture of any other colour. *Atratus* and *nigritus;* when a portion only of something is black; as the point of the glumes of Carex.
20. Black (*niger*); a little tinged with grey. A variety is *nigrescens.*
21. Coal-black (*anthracinus*); a little verging upon blue.
22. Raven-black (*coracinus, pullus*); black, with a strong lustre.
23. Pitch-black (*piceus*); black, changing to brown. From this can scarcely be distinguished brown black (*memnonius*).

IV. Brown.

24. Chestnut-brown (*badius*); dull brown, a little tinged with red.
25. Brown (*fuscus;* in Greek composition, *phæo-*); brown, tinged with greyish or blackish.
26. Deep-brown (*brunneus*); a pure dull brown. Umber-brown (*umbrinus*) is nearly the same.
27. Bright brown (*spadiceus*); pure and very clear brown.
28. Rusty (*ferrugineus*); light brown, with a little mixture of red.
29. Cinnamon (*cinnamomeus*); bright brown, mixed with yellow and red.
30. Red-brown (*porphyreus*); brown, mixed with red.
31. Rufous (*rufus, rufescens*); rather redder than the last.
32. † *Glandaceus;* like the last, but yellower.

33. Liver-coloured (*hepaticus*); dull brown, with a little yellow.
34. Sooty (*fuligineus*, or *fuliginosus*); dirty brown, verging upon black.
35. Lurid (*luridus*); dirty brown, a little clouded.

V. Yellow.

36. Lemon-coloured (*citreus*, or *citrinus*); the purest yellow, without any brightness.
37. Golden yellow (*aureus*, *auratus*; in Greek composition, *chryso-*); pure yellow, but duller than the last, and bright.
38. Yellow (*luteus*; in Greek composition, *xantho-*); such yellow as gamboge.
39. Pale yellow (*flavus*, *luteolus*, *lutescens*, *flavidus*, *flavescens*); a pure but paler yellow than the preceding.
40. Sulphur-coloured (*sulphureus*); a pale lively yellow, with a mixture of white.
41. Straw-coloured (*stramineus*); dull yellow, mixed with white.
42. Leather-yellow (*alutaceus*); whitish yellow.
43. Ochre-colour (*ochraceus*); yellow, imperceptibly changing to brown.
44. *Ochroleucus*; the same, but whiter.
45. Waxy yellow (*cerinus*); dull yellow, with a soft mixture of reddish brown.
46. Yolk of egg (*vitellinus*); dull yellow, just turning to red.
47. Apricot-colour (*armeniacus*); yellow, with a perceptible mixture of red.
48. Orange-colour (*aurantiacus*, *aurantius*); the same, but redder.
49. Saffron-coloured (*croceus*); the same, but deeper and with a dash of brown.
50. *Helvolus*; greyish yellow, with a little brown.
51. Isabella-yellow (*gilvus*); dull yellow, with a mixture of grey and red.
52. Testaceous (*testaceus*); brownish yellow, like that of unglazed earthenware.
53. Tawny (*fulvus*); dull yellow, with a mixture of grey and brown.
54. *Cervinus*; the same, darker.
55. Livid (*lividus*); clouded with greyish, brownish, and bluish.

VI. Green.

56. Grass-green (*smaragdinus*, *prasinus*); clear lively green, without any mixture.
57. Green (*viridis*; in Greek composition, *chloro-*); clear green, but less bright than the last. *Virens*, *virescens*, *viridulus*, *viridescens*, are shades of this.
58. Verdigris-green (*æruginosus*); deep green, with a mixture of blue.
59. Sea-green (*glaucus*, † *thalassicus*, *glaucescens*); dull green, passing into greyish blue.
60. Deep green (*atrovirens*); green, a little verging upon black.
61. Yellowish green (*flavovirens*); much stained with yellow.
62. Olive-green (*olivaceus*; in Greek composition, *elaio-*); a mixture of green and brown.

VII. Blue.

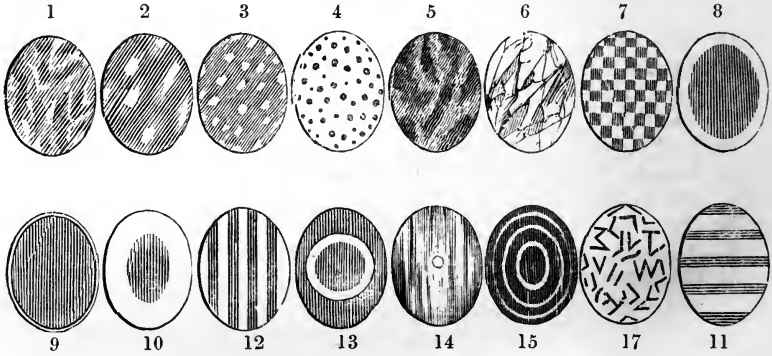
63. Prussian blue (*cyaneus*; in Greek composition, *cyano-*); a clear bright blue.
64. Indigo (*indigoticus*); the deepest blue.
65. Blue (*cæruleus*); something lighter and duller than the last.
66. Sky-blue (*azureus*); a light, pure, lively blue.

67. Lavender-colour (*cæsius*); pale blue, with a slight mixture of grey.
68. Violet (*violaceus, ianthinus*); pure blue stained with red, so as to be intermediate between the two colours.
69. Lilac (*lilacinus*); pale dull violet, mixed a little with white.

VIII. Red.

70. Carmine (*kermesinus, puniceus*); the purest red, without any admixture.
71. Red (*ruber;* in Greek composition, *erythro-*); the common term for any pure red. *Rubescens, rubeus, rubellus, rubicundus,* belonging to this.
72. Rosy (*roseus;* in Greek composition, *rhodo-*); pale pure red.
73. Flesh-coloured (*carneus, incarnatus*); paler than the last, with a slight mixture of red.
74. Purple (*purpureus*); dull red, with a slight dash of blue.
75. Sanguine (*sanguineus*); dull red, passing into brownish black.
76. Phœniceous (*phœniceus, puniceus*); pure lively red, with a mixture of carmine and scarlet.
77. Scarlet (*coccineus*); pure carmine, slightly tinged with yellow.
78. Flame-coloured (*flammeus, igneus*); very lively scarlet, fiery red.
79. Bright red (*rutilans, rutilus*); reddish, with a metallic lustre.
80. Cinnabar (*cinnabarinus*); scarlet, with a slight mixture of orange.
81. Vermilion (*miniatus,* † *vermiculatus*); scarlet, with a decided mixture of yellow.
82. Brick-colour (*lateritius*); the same, but dull and mixed with grey.
83. Brown-red (*rubiginosus, hæmatiticus*); dull red, with a slight mixture of brown.
84. *Xerampelinus;* dull red, with a strong mixture of brown.
85. Coppery (*cupreus*); brownish red, with a metallic lustre.
86. *Githagineus;* greenish red.

8. Of Variegation, or Marking.



1. Variegated (*variegatus*); the colour disposed in various irregular, sinuous spaces.
2. Blotched (*maculatus*); the colour disposed in broad, irregular blotches.
3. Spotted (*guttatus*); the colour disposed in small spots.

4. Dotted (*punctatus*) ; the colour disposed in very small round spots.
5. Clouded (*nebulosus*) ; when colours are unequally blended together.
6. Marbled (*marmoratus*) ; when a surface is traversed by irregular veins of colour ; as a block of marble often is.
7. Tessellated (*tessellatus*) ; when the colour is arranged in small squares, so as to have some resemblance to a tessellated pavement.
8. Bordered (*limbatus*) ; when one colour is surrounded by an edging of another.
9. Edged (*marginatus*) ; when one colour is surrounded by a very narrow rim of another.
10. Discoidal (*discoidalis*) ; when there is a single large spot of colour in the centre of some other.
11. Banded (*fasciatus*) ; when there are transverse stripes of one colour crossing another.
12. Striped (*vittatus*) ; when there are longitudinal stripes of one colour crossing another.
13. Ocellated (*ocellatus*) ; when a broad spot of some colour has another spot of a different colour within it.
14. Painted (*pictus*) ; when colours are disposed in streaks of unequal intensity.
15. Zoned (*zonatus*) ; the same as ocellated, but the concentric bands more numerous.
16. Blurred (*lituratus*). This, according to De Candolle, is occasionally, but rarely, used to indicate spots or rays which seem formed by the abrasion of the surface ; but I know of no instance of such a character.
17. Lettered (*grammicus*) ; when the spots upon a surface assume the form and appearance of letters ; as some Opegraphas.

9. Of Veining.

In terms expressive of this quality the word nerves is generally used, but very incorrectly.

1. Ribbed (*nervosus*, † *nervatus*) ; having several ribs ; as Plantago lanceolata, &c.
2. One-ribbed (*uninervis*, † *uninervatus*, *costatus*) ; when there is only one rib ; as in most leaves.
3. Three-ribbed (*trinervis*) ; when there are three ribs all proceeding from the base ; as in Chironia Centaurium. *Quinquenervis*, when there are five ; as in Gentiana lutea. *Septemnervis*, when there are seven ; as in Alisma Plantago ; and so on.
4. Triple-ribbed (*triplinervis*) ; when of three ribs the two lateral ones emerge from the middle one a little above its base ; as in Melastoma multiflora. *Quintuplinervis*, &c., are used to express the obvious modifications of this.
5. † *Indirectè venosus ;* when the lateral veins are combined within the margin, and emit other little veins. *Link.*
6. † *Evanescenti-venosus ;* when the lateral veins disappear within the margin. *Id.*
7. † *Combinatè venosus ;* when the lateral veins unite before they reach the margin. *Id.*
8. † Straight-ribbed († *rectinervis*, † *parallelinervis*, *directè venosus*, Link) ; when the lateral ribs are straight ; as in Alnus glutinosa, Castanea vesca, &c.,

Mirb. When the ribs are straight and almost parallel, but united at the summit; as in Grasses. *De Cand.*

9. † Curve-ribbed († *curvinervis*, † *converginervis*); when the ribs describe a curve, and meet at the point; as in Plantago lanceolata.
10. † *Ruptinervis;* when a straight-ribbed leaf has its ribs interrupted at intervals. *De Cand.*
11. † *Penniformis;* when the ribs are disposed as in a pinnated leaf, but confluent at the point; as in the Date. *De Cand.*
12. † *Palmiformis;* when the ribs are arranged as in palmate leaves; as in the Chamærops. *Id.*
13. † *Penninervis;* when the ribs are pinnated (*De Cand.*); as in Castanea vesca.
14. † *Pedatinervis;* when the ribs are pedate. *De Cand.*
15. † *Palminervis;* when they are palmated. *Id.*
16. † *Peltinervis;* when they are peltate. *Id.*
17. † *Vaginervis;* when the veins are arranged without any order; as in Ficoideæ. *Id.*
18. † *Retinervis;* when the veins are reticulated, or like lace. *Id.*
19. † *Nullinervis*, or *Enervis;* when there are no ribs or veins whatever. *Id.*
20. † *Falsinervis;* when the veins have no vascular tissue, but are formed of simple, elongated, cellular tissue; as in Mosses, Fuci, &c.
21. † *Hinoideus;* when all the veins proceed from the midrib, and are parallel and undivided; as in Scitamineæ. *Link.* When they are connected by little cross veins, the term is † venuloso-hinoideus. *Id.*
22. † *Venosus;* when the lateral veins are variously divided. *Id.*

II. *Of Individual Relative Terms.*

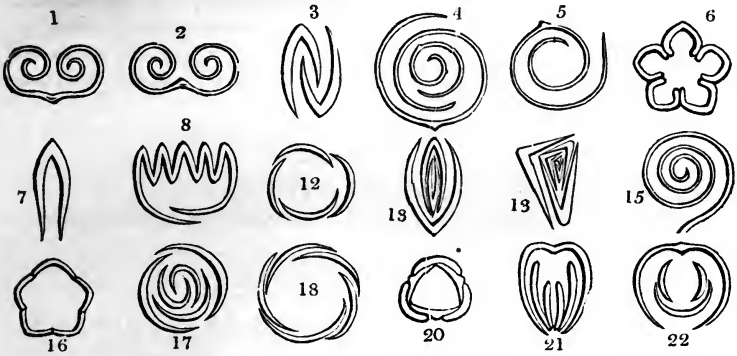
These are arranged under the heads of *Estivation*, or the relation which organs bear to each other in the bud state; *Direction*, or the relation which organs bear to the surface of the earth, or to the stem of the plant which forms the axis, either real or imaginary, round which they are disposed; and *Insertion*, or the manner in which one part is inserted into, or adheres to, another.

1. Of Estivation.

The term *estivation*, or *præfloration*, is applied to the parts of the flower when unexpanded; and *vernation* is expressive of the foliage in the same state. The ideas of their modifications, are, however, essentially the same.

1. Involute (*involutiva, involuta*); when the edges are rolled inwards spirally on each side (*Link*); as the leaf of the Apple.
2. Revolute (*revolutiva, revoluta*); when the edges are rolled backwards spirally on each side (*Link*); as in the leaf of the Rosemary.
3. Obvolute (*obvolutiva, obvoluta*, Link; *semi-amplexa*, De Cand.); when the margins of one alternately overlap those of that which is opposite to it.
4. Convolute (*convolutiva, convoluta*); when one is wholly rolled up in another, as in the petals of the Wallflower.
5. Supervolute (*supervolutiva*); when one edge is rolled inwards, and is enveloped by the opposite edge rolled in an opposite direction; as the leaves of the Apricot.

6. Induplicate (*induplicativa*) ; having the margins bent abruptly inwards, and the external face of these edges applied to each other without any twisting ; as in the flowers of some species of Clematis.



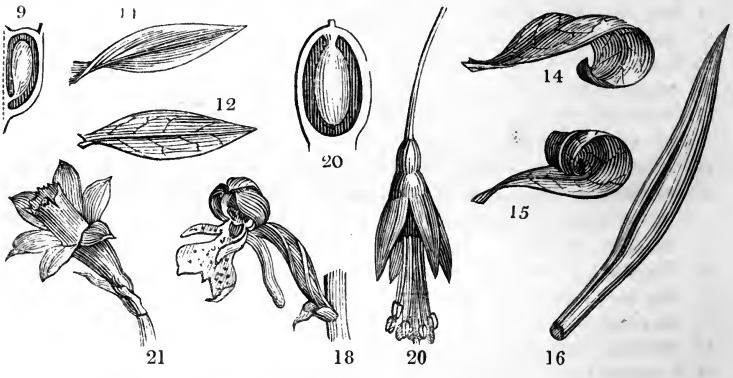
7. Conduplicate (*conduplicativa, conduplicata*) ; when the sides are applied parallelly to the faces of each other.
8. Plaited (*plicativa, plicata*) ; folded lengthwise, like the plaits of a closed fan ; as the Vine and many Palms.
9. Replicate (*replicativa*) ; when the upper part is curved back and applied to the lower ; as in the Aconite.
10. Curvative (*curvativa*) ; when the margins are slightly curved, either backwards or forwards, without any sensible twisting. *De Cand.*
11. Wrinkled (*corrugata, corrugativa*) ; when the parts are folded up irregularly in every direction ; as the petals of the Poppy.
12. Imbricated (*imbricativa, imbricata*) ; when they overlap each other parallelly at the margins, without any involution. This is the true meaning of the term. M. De Candolle applies it in a different sense. (*Théorie*, ed. 1., p. 399.)
13. Equitant (*equitativa, equitans*, Link ; *amplexa*, De Cand.) ; when they overlap each other parallelly and entirely, without any involution ; as the leaves of Iris.
14. Reclinate (*reclinata*) ; when they are bent down upon their stalk.
15. Circinate (*circinatus*) ; when they are rolled spirally downwards.
16. Valvate (*valvata, valvaris*) ; applied to each other by the margins only ; as the petals of Umbelliferæ, the valves of a capsule, &c.
17. Quincunx (*quincuncialis*) ; when the pieces are five in number, of which two are exterior, two interior, and the fifth covers the interior with one margin, and has its other margin covered by the exterior ; as in Rosa.
18. Twisted (*torsiva, spiraliter contorta*) ; the same as contorted, except that there is no obliquity in the form or insertion of the pieces : as in the petals of Oxalis.
19. Contorted (*contorta*) ; each piece being oblique in figure, and overlapping its neighbour by one margin, its other margin being, in like manner, overlapped by that which stands next it : as Apocyneæ.
20. Alternative (*alternativa*) ; when, the pieces being in two rows, the inner is

covered by the outer in such a way that each of the exterior rows overlaps half of two of the interior ; as in Liliaceæ.

21. Vexillary (*vexillaris*) ; when one piece is much larger than the others, and is folded over them, they being arranged face to face ; as in papilionaceous flowers.
22. Cochlear (*cochlearis*) ; when one piece, being larger than the others, and hollowed like a helmet or bowl, covers all the others ; as in Aconitum, some species of personate plants, &c.

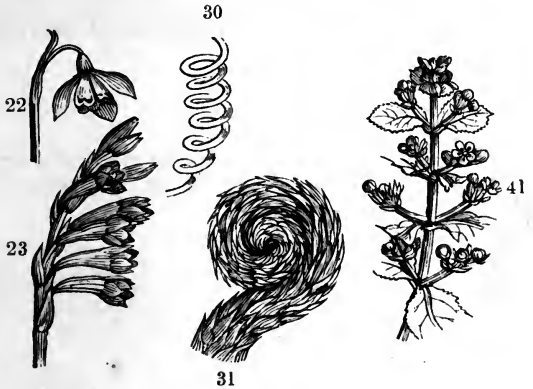
2. Of Direction.

1. Erect (*erectus, arrectus*) ; pointing towards the zenith.
2. Straight (*rectus*) ; not wavy or curved, or deviating from a straight direction in any way.
3. Very straight (*strictus*) ; the same as the last, but in excess.
4. Swimming (*natans*) ; floating under water ; as Confervæ.
5. Floating (*fluitans*) ; floating upon the surface of water ; as the leaves of Nuphar.
6. Submersed (*submersus, demersus*) ; buried beneath water.
7. Descending (*descendens*) ; having a direction gradually downwards.
8. Hanging down (*dependens*) ; having a downward direction, caused by its own weight.



9. Ascending (*ascendens, assurgens*) ; having a direction upwards, with an oblique base ; as many seeds.
10. Perpendicular (*verticalis, perpendicularis*) ; being at right angles with some other body.
11. Oblique (*obliquus*) ; when the margin points to the heavens, the apex to the horizon ; as the leaves of Protea and Fritillaria.
12. Horizontal (*horizontalis*) ; when the plane points to the heavens, the apex to the horizon, as most leaves.
13. Inverted (*inversus*) ; having the apex of one thing in an opposite direction to that of another ; as many seeds.
14. Revolute (*revolutus*) ; rolled backwards from the direction ordinarily assumed by similar other bodies ; as certain tendrils, and the ends of some leaves.

15. Involute (*involutus*) ; rolled inwards.
16. Convolute (*convolutus*) ; rolled up.
17. Reclining (*reclinatus*) ; falling gradually back from the perpendicular ; as the branches of the Banyan tree.
18. Resupinate (*resupinatus*) ; inverted in position by a twisting of the stalk ; as the flowers of Orchis.
19. † Inclining († *inclinatus, declinatus*) ; the same as reclining, but in a greater degree.
20. Pendulous (*pendulus*) ; hanging downwards, in consequence of the weakness of its support.
21. Drooping (*cernuus*); inclining a little from the perpendicular, so that the apex is directed towards the horizon.

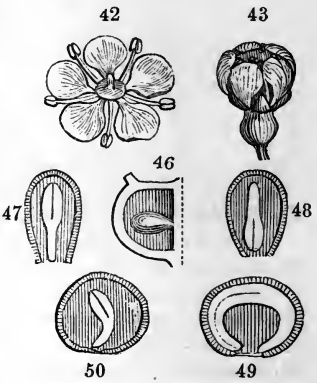


22. Nodding (*nutans*); inclining very much from the perpendicular, so that the apex is directed downwards.
23. One-sided (*secundus*); having all the parts by twists in their stalks turned one way ; as the flowers of Antholyza.
24. Inflexed (*inflexus, incurvus, introflexus, introcurvus, infractus*); suddenly bent inwards.
25. Reflexed (*reflexus, recurvus, retroflexus, retrocurvus, refractus*); suddenly bent backwards.
26. Deflexed (*deflexus, declinatus*); bent downwards.
27. Flexuose (*flexuosus*); having a gently bending direction, alternately inwards and outwards.
28. Tortuous (*tortuosus*) ; having an irregular, bending, and turning direction.
29. Knee-jointed (*geniculatus*); bent abruptly like a knee ; as the stems of many Grasses.
30. Spiral (*spiralis, anfractuosus*); resembling in direction the spires of a cork-screw, or other twisted thing.
31. Circinate (*circinatus, gyratus, circinalis*) ; bent like the head of a crosier ; as the young shoots of Ferns.
32. Twining (*volubilis*) ; having the property of twisting round some other body.

a. To the right hand, or *dextrorsum;* when the twisting is from left to right, or in the direction of the sun's course; as the Hop.

b. To the left hand (*sinistrorsum*); when the twisting is from right to left, or opposite to the sun's course; as Convolvulus sepium.

33. Turned backwards (*retrorsus*); turned in a direction opposite to that of the apex of the body to which the part turned appertains.
34. Turned inwards (*introrsus, anticus*); turned towards the axis to which it appertains.
35. Turned outwards (*extrorsus, posticus*); turned away from the axis to which it appertains.
36. Procumbent (*procumbens, humifusus*); spread over the surface of the ground.
37. Prostrate (*prostratus, pronus*); lying flat upon the earth, or any other thing.
38. Decumbent (*decumbens*); reclining upon the earth, and rising again from it at the apex.
39. Diffuse (*diffusus*); spreading widely.
40. Straggling (*divaricatus*); turning off from anything irregularly, but at almost a right angle; as the branches of many things.
41. Brachiate (*brachiatus*); when ramifications proceed from a common axis nearly at regular right angles, alternately in opposite directions.
42. Spreading (*patens*); having a gradually outward direction; as petals from the ovarium.
43. Converging (*connivens*); having a gradually inward direction; as many petals.
44. Opposite (*adversus, + oppositus*); pointing directly to a particular place; as the radicle to the hilum.
45. Uncertain (*vagus*); having no particular direction.
46. Peritropal (*peritropus*); directed from the axis to the horizon. This and the four following are only applied to the embryo of the seed.
47. Orthotropal (*orthotropus*); straight, and having the same direction as the body to which it belongs.
48. Antitropal (*antitropus*); straight, and having a direction contrary to that of the body to which it belongs.
49. Amphitropal (*amphitropus*); curved round the body to which it belongs.
50. Homotropal (*homotropus*); having the same direction as the body to which it belongs, but not being straight.

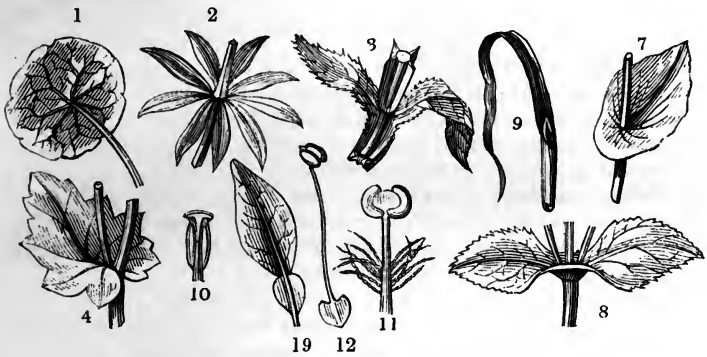


3. Of Insertion.

A. *With respect to the Mode of Attachment or of Adhesion.*

1. Peltate (*peltatus, umbilicatus*); fixed to the stalk by the centre, or by some point distinctly within the margin; as the leaf of Tropæolum.

2. Sessile (*sessilis*) ; sitting close upon the body that supports it, without any sensible stalk.
3. Decurrent (*decurrens, decursivus*) ; prolonged below the point of insertion, as if running downwards.



4. Embracing (*amplectans*) ; clasping with the base.
5. Stem-clasping (*amplexicaulis*) ; the same as the last, but applied only to stems.
6. Half-stem-clasping (*semi-amplexicaulis*) ; the same as the last, but in a smaller degree.
7. Perfoliate (*perfoliatus*) ; when the two basal lobes of an amplexicaul leaf are united together, so that the stem appears to pass through the substance of the leaf.
8. Connate (*connatus*) ; when the bases of two opposite leaves are united together.
9. Sheathing (*vaginans*) ; surrounding a stem or other body by the convolute base : this chiefly occurs in the petioles of Grasses.
10. Adnate (*adnatus, annexus*) ; adhering to the face of a thing.
11. Innate (*innatus*) ; adhering to the apex of a thing.
12. Versatile (*versatilis,* † *oscillatorius*) ; adhering slightly by the middle, so that the two halves are nearly equally balanced, and swing backwards and forwards.
13. Stipitate (*stipitatus*) ; elevated on a stalk which is neither a petiole nor a peduncle.
14. † Palaceous († *palaceus*) ; when the foot-stalk adheres to the margin. *Willd.*
15. Separate († *solutus, liber,* † *distinctus*) ; when there is no cohesion between parts.
16. Accrete (*accretus*) ; fastened to another body, and growing with it. *De Cand.*
17. Adhering (*adhærens*) ; united laterally by the whole surface with another organ. *De Cand.*
18. Cohering (*cohærens,* † *coadnatus, coadunatus,* † *coalitus,* † *connatus, confluens*) ; this term is used to express, in general, the fastening together of homogeneous

parts. *De Cand.* Such are De Candolle's definitions of these three terms; but in practice there is no difference between them.

19. Articulated (*articulatus*) ; when one body is united with another by a manifest articulation.

B. *With respect to Situation.*

1. Dorsal (*dorsalis*) ; fixed upon the back of any thing.
2. Lateral (*lateralis*) ; fixed near the side of any thing.
3. Marginal (*marginalis*) ; fixed upon the edge of any thing.
4. Basal (*basilaris*) ; fixed at the base of any thing.
5. Radical (*radicalis*) ; arising from the root.
6. Cauline (*caulinus*) ; arising from the stem.
7. Rameous (*rameus, ramealis*) ; of or belonging to the branches.
8. Axillary (*axillaris, + alaris*); arising out of the axilla.
9. Floral (*floralis*); of or belonging to the flower.
10. Epiphyllous (*foliaris, epiphyllus*); inserted upon the leaf.
11. Terminal (*terminalis*); proceeding from the end.
12. Of the leaf-stalk (*petiolaris*); inserted upon the petiole.
13. Crowning (*coronans*); situated on the top of anything. Thus, the limbs of the calyx may crown the ovary ; a gland at the apex of the filament may crown the stamen ; and so on.
14. Epigeous (*epigæus*); growing close upon the earth.
15. Subterranean (*hypogæus, + subterraneus*); growing under the earth.
16. Amphigenous (*amphigenus*); growing all round an object.
17. Epigynous (*epigynus*); growing upon the summit of the ovarium.
18. Hypogynous (*hypogynus*); growing from below the base of the ovarium.
19. Perigynous (*perigynus*) ; growing upon some body that surrounds the ovarium.

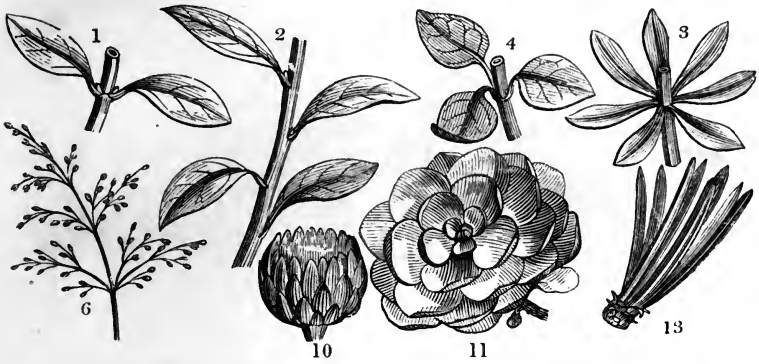
Class II. Of Collective Terms.

It has been already explained, that collective terms are those which apply to plants, or their parts, considered in masses ; by which is meant that they cannot be applied to any one single part or thing, without a reference to a larger number being either expressed or understood. Thus, when leaves are said to be *opposite*, that term is used with respect to several, and not to one ; and when a panicle is said to be lax, or loose, it means that the flowers of a panicle are loosely arranged; and so on.

1. Of Arrangement.

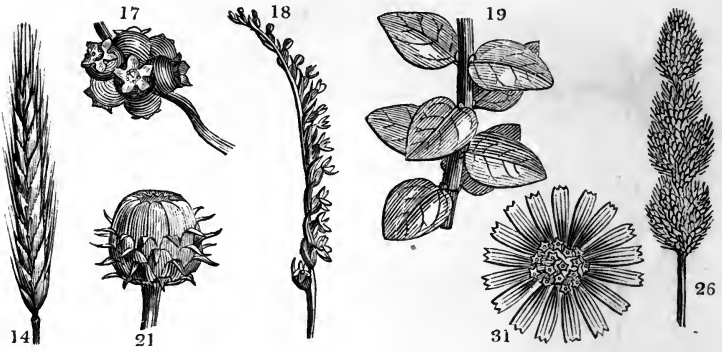
1. Opposite (*oppositus*); placed on opposite sides of some other body or thing on the same plane. Thus, when leaves are opposite, they are on opposite sides of the stem ; when petals are opposite, they are on opposite sides of the ovary ; and so on.
2. Alternate (*alternus*); placed alternately one above the other on some common body, as leaves upon the stem.
3. Stellate (*stellatus, stelliformis, stellulatus*); the same as verticillate, No. 4., except that the parts are narrow and acute.

4. Whorled (*verticillatus*); when several things are in opposition round a common axis, as some leaves round their stem; sepals, petals, and stamens round the ovarium, &c.



5. Ternate (*ternus*); when three things are in opposition round a common axis.
6. Loose (*laxus*); when the parts are distant from each other, with an open light kind of arrangement; as the panicle among the other kinds of inflorescence.
7. Scattered (*sparsus*); used in opposition to whorled, or opposite, or ternate, or other such terms.
8. Compound (*compositus*); when formed of several parts united in one common whole; as pinnated leaves, all kinds of inflorescence beyond that of the solitary flower.
9. Crowded (*confertus*); when the parts are pressed closely round about each other.
10. Imbricated (*imbricatus*); when parts lie over each other in regular order, like tiles upon the roof of a house; as the scales upon the cup of some acorns.
11. Rosulate (*rosulatus, rosularis*); when parts which are not opposite, nevertheless become apparently so by the contraction of the joints of the stem, and lie packed closely over each other, like the petals in a double rose; as in the offsets of Houseleek.
12. Cæspitose (*cæspitosus*); forming dense patches, or turfs; as the young stems of many plants.
13. Fascicled (*fasciculatus*); when several similar things proceed from a common point; as the leaves of the Larch, for example.
14. Distichous (*distichus, bifarius*); when things are arranged in two rows, the one opposite to the other; as the florets of many Grasses.
15. In rows (*serialis*); arranged in rows which are not necessarily opposite each other: *biserialis*, in two rows; *triserialis*, in three rows: but these are seldom used. In their stead, we generally add *fariam* to the end of a Latin numeral: thus, *bifariam* means in two rows; *trifariam* in three rows; and so on.
16. One-sided (*unilateralis, secundus*); arranged on, or turned towards, one side only; as the flowers of Antholyza.

17. Clustered (*aggregatus, coacervatus, conglomeratus*); collected in parcels, each of which has a roundish figure; as the flowers of Cuscuta, Adoxa, Trientalis, &c.



18. Spiral (*spiralis*); arranged in a spiral manner round some common axis; as the flowers of Spiranthes.
19. Decussate (*decussatus*); arranged in pairs that alternately cross each other; as the leaves of many plants.
20. Fastigiate (*fastigiatus*); when all the parts are nearly parallel, with each pointing upwards to the sky; as the branches of Populus fastigiata, and many other trees.
21. Squarrose (*squarrosus*); when the parts spread out at right angles, or thereabouts, from a common axis; as the leaves of some Mosses, the involucra of some Compositæ, &c.
22. Fasciated (*fasciatus*); when several contiguous parts grow unnaturally together into one; as the stems of some plants, the fruits of others, &c.
23. Scaly (*squamosus*); covered with small scales, like leaves.
24. Starved (*depauperatus*); when some part is less perfectly developed than is usual with plants of the same family. Thus, when the lower scales of a head of a Cyperaceous plant produce no flowers, such scales are said to be starved.
25. Distant (*distans, remotus, rarus*); in contradiction to imbricated, or dense, or approximated, or any such words.
26. Interrupted (*interruptus*); when any symmetrical arrangement is destroyed by local causes, as, for example, a spike is said to be interrupted when here and there the axis is unusually elongated, and not covered with flowers; a leaf is interruptedly pinnated when some of the pinnæ are much smaller than the others, or wholly wanting; and so on.
27. Continuous, or uninterrupted (*continuus*); the reverse of the last.
28. Entangled (*intricatus*); when things are intermixed in such an irregular manner that they cannot be readily disentangled; as the hairs, roots, and branches of many plants.
29. Double, or twin († *duplicatus, geminatus*); growing in pairs.
30. Rosaceous (*rosaceus*); having the same arrangement as the petals of a single rose.

31. Radiant (*radiatus*); diverging from a common centre, like rays; as the ligulate florets of any compound flower.

2. Of Number.

1. None (*nullus*); absolutely wanting.
2. Numerous (*numerosus*); so many that they cannot be counted with accuracy; or several, but not of any definite number.
3. Solitary (*solitarius, unicus*); growing singly.
4. Many (in Greek compounds, *poly-*); has the same meaning as numerous.
5. Few (in Greek compounds, *oligo-*); means that the number is small, not indefinite. It is generally used in contrast with many (*poly-*) when no specific number is employed; as in the definition of things the number of which is definite, but variable.

Besides the above, De Candolle has the following Table of Numbers (*Théorie*, 502.):—

Derived from the Latin.	Derived from the Greek.	Power.
uni	mono	1.
bi	di	2.
tri	tri	3.
quadri	tetra	4.
quinque	penta	5.
sex	hexa	6.
septem	hepta	7.
octo	octo	8.
novem	ennea	9.
decem	deca	10.
undecim	endeca	11.
duodecim	dodeca	12, or from 11 to 19.
viginti	icos	20.
pauci	oligos	a small number.
pluri	- -	a middling number.
multi	poly	a great number.
bini, gemini	- -	2 together.
terni, ternati	- -	3 together.
quaterni, quaternati	- -	4 together.
quini, quinati	- -	5 together.
seni	- -	6 together.
septeni	- -	7 together.
octoni	- -	8 together.
noni, noveni	- -	9 together.
deni, † denarii	- -	10 together.
duodeni	- -	12 together.
viceni	- -	20 together.
simplici	- -	solitary, or simple.
duplici	- -	double.
triplici	- -	triple.
quadruplici	- -	quadruple.
quintuplici	- -	quintuple.
sextuplici	- -	sextuple.
multiplici	- -	multiple.
tripli	- -	triple, only applied to the ribs of leaves.

Class III. Of Terms of Qualification.

Terms of qualification are generally syllables prefixed to words of known signification, the value of which is altered by such addition. These syllables are often Latin prepositions.

1. *Ob*, prefixed to a word, indicates inversion: thus, *ob*ovate means inversely ovate; *ob*cordate, inversely cordate; *ob*conical, inversely conical; and so on. Hence it is evident that this prefix cannot be properly applied to any terms except such as indicate that one end of a body is wider than the other; for, if both ends are alike, there can be no apparent inversion: therefore when the word *ob*lanceolate is used, as by some French writers, it literally means nothing but lanceolate; for that figure, being strictly regular, cannot be altered in figure by inversion.
2. *Sub*, prefixed to words, implies a slight modification, and may be Englished by somewhat: as, *sub*ovate means somewhat ovate; *sub*viridis, somewhat green; *sub*rotundus, somewhat round; *sub*purpureus, somewhat purple; and so on. The same effect is also given to a term by changing the termination into *ascens*, or *escens*: thus, virid*escens* signifies greenish; rub*escens*, reddish; and so on.

Signs.

In Botany a variety of marks, or signs, are employed to express particular qualities or properties of plants. The principal writers who have invented these signs are, Linnæus, Willdenow, De Candolle, Trattinnick, and Loudon.

* *Linn.*, *Willd.*, *De Cand.*, *Tratt.*, indicates that a good description will be found at the reference to which it is affixed.

† *Linn.*, *Wild.*, *De Cand.*, *Tratt.*, indicates that some doubt or obscurity relates to the subject to which it is affixed.

/ *De Cand.*, shows that an authentic specimen has been examined from the author to whose name or work it is annexed.

? The note of interrogation varies in its effect, according to the place in which it is inserted. When found after a specific name, as *Papaver cambricum?* it signifies that it is uncertain whether the plant so marked is that species, or some other of the genus; if after the generic name, as *Papaver? cambricum*, it shows an uncertainty whether the plant so marked belongs to the genus Papaver; when found affixed to the name of an author, as *Papaver cambricum* Linn., Smith, Lam.?, it signifies that, while there is no doubt of the plant being the same as one described under that name by Linnæus and Smith, it is doubtful whether it is not different from that of Lamarck. It may be remarked, that when the interrogation has a general, and not a particular, application, it should be placed at the commencement of the paragraph; as *? Papaver cambricum* Smith, &c., not *Papaver cambricum* Smith ?, &c., as is the usual practice.

♄ *Linn. Willd.* A tree or shrub.

♅ *Loudon.* A deciduous tree.

♇ *Loudon.* An evergreen tree.

♄ *Tratt.* A true tree; as the Oak.

♄ *De Cand.* An under shrub; as Laurustinus.

♅ *Loudon.* A deciduous undershrub.

Loudon. An evergreen under-shrub.

De Cand., *Tratt.* Caulocarpous.

De Cand., *Tratt.* A shrub.

Loudon. A deciduous shrub.

Loudon. An evergreen shrub.

De Cand. A small tree. A tree more than twenty-five feet high.

Tratt., *Loudon.* A simple-stemmed arborescent monocotyledonous tree; such as a Palm.

Linn., *Willd.*, *De Cand.*, *Tratt.*, *Loudon.* A perennial.

De Cand. Monocarpous in general.

De Cand., *Tratt.* A monocarpous perennial.

Linn., *Willd.*, *Tratt.*, *De Cand.*, *Loudon.* Annual.

Linn., *Willd.*, *De Cand.*, *Tratt.*, *Loudon.* Biennial.

Tratt. Propagated by new tubers, which perish as soon as they have borne a plant; as the Potato.

Tratt. Propagated by suckers; as Poa pratensis.

Tratt. Propagated by runners; as the Strawberry.

Tratt. Viviparous; increasing by buds which fall from it; as Lilium tigrinum.

Tratt. Stemless; as Carduus acaulis.

Tratt. A plant whose flowers are borne upon a scape; as Hieracium Pilosella.

Tratt. A plant which bears its flowers and leaves upon two separate stems, as Curcuma Zedoaria. This sort of plant is called by Trattinnick *heterophytous.*

Tratt., *Loudon.* A calamarious, or grassy, plant; as Bromus mollis.

De Cand., *Tratt.* A twining plant.

De Cand. Which twines to the right.

De Cand. Which twines to the left.

Loudon. A deciduous twining plant.

Loudon. An evergreen twining plant.

Loudon. A deciduous climbing plant.

Loudon. An evergreen climbing plant.

Loudon. A deciduous trailing plant.

Loudon. An evergreen trailing plant.

Loudon. A deciduous creeping plant.

Loudon. An evergreen creeping plant.

Loudon. A deciduous herbaceous plant.

Loudon. An evergreen herbaceous plant.

Loudon. A bulbous plant.

Loudon. A fusiform-rooted plant.

Loudon. A tuberous-rooted plant.

Loudon. An aquatic plant.

Loudon. A parasitical plant.

De Cand., *Tratt.* An evergreen plant.

De Cand., *Tratt.* An indefinite number.

Willd., &c. The male sex.

Willd., &c. The female sex.

Willd., &c. The hermaphrodite sex.

Willd. The neuter sex.

♂—♀	*Willd.*	Monœcious; or the male and female on one plant.
♒	*Tratt.*	
♂ : ♀	*Willd.*	Dicœcious; or the male and female on different plants.
♋	*Tratt.*	
☿ | ♀	*Willd.*	Hermaphrodite and female in one compound flower.
☿ | ♄	*Willd.*	Hermaphrodite and neuter in one compound flower.
☿—♂	*Willd.*	Hermaphrodite and male on one stem.
☿—♀	*Willd.*	Hermaphrodite and female on one stem.

Abbreviations.

These are only known in the botanical works which are written in Latin: they are of little importance, and, as will be seen by the mark † prefixed, are scarcely ever used. The following list is chiefly taken from Trattinnick. (*Synodus*, i. 16.):—

†	Æst.	*Æstate.*
	Alb.	*Albumen.*
†	Alp.	*Alpes, Alpinus.*
	Anth.	*Anthera, Anthodium, Anthesis.*
	Apr.	*Aprilis, Apricus.*
†	Ar.	*Arena, Arenosus.*
†	Art.	*Artificialis.*
	Arv.	*Arva, Arvensis.*
†	Aug.	*Augustus.*
†	Augm.	*Augmentum.*
	Aut.	*Autumnus, Autumnalis.*
	B.	*Beatus* or *Defunctus;* used in speaking of a person who is recently deceased, and is equivalent to our English word "late."
	Br.	*Bractea.*
	Cal.	*Calyx.*
	Cald.	*Caldarium.*
†	Camp.	*Campus, Campestris.*
†	Carpell.	*Carpellum.*
†	Carpid.	*Carpidium.*
†	Carpol.	*Carpologia.*
	Cel.	*Celeberrimus.*
	Char.	*Character, Characteristicus.*
	Cl.	*Clarissimus, Classis.*
†	Coll.	*Collis, Collinus, Collectanea.*
	Cor.	*Corolla, Corollarium.*
†	Cot.	*Cotyledon.*
	Cult.	*Cultus, Cultura.*
	Dec.	*December, Decas, Decandria.*
	Desc.	*Descriptio.*
†	Des.	*Desideratur.*
	Diff.	*Differentia.*
†	Diss.	*Dissepimentum, Dissertatio.*
†	Dum.	*Dumetum.*
	Ed.	*Editio, Editor, Edulis.*
	Embr.	*Embryo.*
	Ess.	*Essentialis.*
†	Excl.	*Exclusio.*
	Fam.	*Familia.*
	Feb.	*Februarius.*
	Fil.	*Filamentum.*
	Fl.	*Flos, Flumen, Floret, Floralis.*
	Fol.	*Folium.*
	Fr.	*Fructus.*
	Fructif.	*Fructificatio.*
†	Fun.	*Funiculus umbilicalis.*
	Gen.	*Genus, Genericus.*
	Germ.	*Germen.*
†	Glar.	*Glareosus.*
	H.	*Herbarium, Habitat.*
	Hab.	*Habitat, Habeo.*
	Herb.	*Herbarium, Herba.*
†	Hexap.	*Hexapodium.*
	Hort.	*Hortus.*
†	Hortul.	*Hortulanus, Hortulanorum, Hortulus.*
†	Hosp.	*Hospes, Hospitator.*
†	Hum.	*Humidus, Humus.*
	Ic.	*Icon, b.* bona, *m.* mala, *p.* picta, *l.* lignea, *n.* nigra.
	Ill.	*Illustratio, Illustris.*

† Ined.	*Ineditus, Inedulis.*
Ind.	*Indicus; India, a.* australis, *or.* orientalis, *occ.* occidentalis; *Index.*
Inf.	*Inferus.*
Infl.	*Inflorescentia.*
† Inund.	*Inundatus.*
Jan.	*Januarius.*
Jul.	*Julius.*
Jun.	*Junius, Junior.*
† Juv.	*Juvenis, Juventus.*
Lat.	*Latus, Latitudo, Lateralis.*
† Lin.	*Linea, Linearis.*
Lit.	*Litera.*
† Litt.	*Littus, Littoralis.*
L. c.	*Loco citato.*
† Loc.	*Loculamentum, Locusta.*
Long.	*Longus, Longitudo.*
† Maj.	*Majus.*
† Mar.	*Mare, Marinus.*
† Mat.	*Matutinus, Maturus.*
Mart.	*Martius.*
Mont.	*Montes, Montanus.*
Mss.	*Manuscripta.*
† Mus.	*Museum.*
† N.	*Numerus.*
Nat.	*Naturalis.*
† Nem.	*Nemus, Nemorosus.*
No.	*Numero.*
Nom.	*Nomen, gen.* genericum, *triv.* trivale, *s.* specificum, *barb.* barbarum, *leg.* legale, *syn.* synonymum.
Obs.	*Observatio, Observandum.*
Oct.	*Octobris.*
† Or.	*Origo, Originarium, Oriens, Orientale.*
Ord.	*Ordo, Ordinarium.*
Ov.	*Ovarium.*
P.	*Pagina, Pars.*
† Pal.	*Paludes, Paludosus.*
Ped.	*Pedunculus.*
Peric.	*Pericarpium.*
Perig.	*Perigonium.*
Pet.	*Petalum, Petiolus.*
† Phyll.	*Phyllum, Phyllodium.*
Pist.	*Pistillum.*
Plac.	*Placenta.*
Poll.	*Pollen, Pollicaris.*
† Pom.	*Pomeridianum, Pomum.*
† Pr. v.	*Primo vere.*
Rad.	*Radix, Radius, Radiatus.*
Ram.	*Ramus, Rameus, Ramosus.*
† Rec.	*Receptaculum, Recapitulatio.*
S.	*Seu, Sive.*
† Salt.	*Saltus, Saltuarium.*
Sect.	*Sectio vel Divisio.*
† Segm.	*Segmentum.*
Sem.	*Semen, Semis.*
Sep.	*Sepalum, Sepes.*
Sept.	*September, Septum.*
† Ser.	*Series.*
Sicc.	*Siccum.*
Sp.	*Species, Specificus.*
Spont.	*Spontaneus.*
† Spor.	*Sporula.*
† Sporang.	*Sporangium.*
Stam.	*Stamen, Stamineum.*
Stigm.	*Stigma.*
Stip.	*Stipes, Stipula, Stipularis.*
Styl.	*Stylus.*
Subd.	*Subdivisio.*
Subv.	*Subvarietas.*
Sup.	*Superus.*
† Sylv.	*Sylvestris, Sylva.*
Syn.	*Synonymum, Synopsis, Synodus.*
T.	*Tabula, Tomus.*
† Temp.	*Tempestas, Temperatura.*
† Tep.	*Tepidarium.*
Trib.	*Tribus, Divisio.*
† Triv.	*Trivialis.*
† Turf.	*Turfosus.*
V.	*Volumen, Vide, Vel, Vulgo.*
Var.	*Varietas.*
V. s. c.	*Vidi siccam cultam.*
V. s. s.	*Vidi siccam spontaneam.*
V. v. c.	*Vidi vivam cultam.*
V. v. s.	*Vidi vivam spontaneam.*
Veg.	*Vegetabile, Vegetatio.*
† Vern.	*Vernalis, Vernaculum.*
† Vert.	*Vertex, Verticalis.*
† Vesc.	*Vesca, Vescarium.*
† Vir.	*Viridarium, Viris, Viridis.*
† Visc.	*Viscosus, Viscositas.*
† Volv.	*Volva, Volvaceus.*

The following excellent Table of Abbreviations was contrived by the late Mr. Ferdinand Bauer, to express all the subjects for which illustrations are required in botanical drawings. It has been adopted in Endlicher's *Iconographia Generum Plantarum*, and it is to be wished that these abbreviations, which are in every way unexceptionable, should be universally adopted for references to plates: they would not only form a common means of comparison between the figures of different authors, but would also keep continually within the view of artists the nature of the subjects they are employed to analyse. It may be added that the Table, if considered without reference to the abbreviations, is in itself an excellent sketch of the principal modes, degrees, and analogies of the regular development of fructification. When the letters used are capitals, they indicate that the object is magnified; when small, that it is of the natural size; when with a score (—) drawn beneath them, that it is less than the natural size.

a. A flower before expansion.
a 1. A flower expanded.
b. The operculum of a flower; generally formed by the confluence of the calyx and corolla.
c. The perianthium; the floral integument of monocotyledonous plants, and the generally simple one of dicotyledones. (Corolla of Linnæus; calyx of Jussieu.)
c 1. External leaflets of the perianthium; having generally the nature of a calyx. (Calyx of Linnæus.)
c 2. Internal leaflets of the perianthium, except c 3. and c 4.; having usually the texture of petals. (Corolla of Linnæus.)
c 3. The labellum, or its appendages. In Orchids.
c 4. The hypogynous scales of Grasses. (Nectarium of Linnæus.)
c 5. Appendages of the perianthium.
d. The calyx.
e. A monopetalous corolla.
e 1. Petals.
e 2. Appendages of the corolla. (Nectarium of Linnæus; parapetala of Ehrhart.)
f. The discus, whether hypogynous or epigynous.
f 1. Scales or glands, whether hypogynous or epigynous.
g. Sexual organs combined in a column; in Orchidaceæ and Stylidiaceæ.
g 1. Sexual organs separate; the floral envelopes being removed.
h. The stamens.
h 1. An anther.
h 2. Pollen.
h 3. Pollen masses; in Orchidaceæ and Asclepiadaceæ.
h 4. Sterile stamens.
h 5. The corona of a tube of stamens; in Asclepiadaceæ. (Nectarium of Linnæus.)
i. The pistil.
i 1. The ovarium.
i 2. The stigma.
i 3. The indusium of the stigma; in Goodeniaceæ and Brunoniaceæ.
i 4. An ovulum.
l. A compound fruit; common to several flowers.
l 1. Several distinct pericarpia; belonging to a single flower.
m. Induviæ; the remains of the flower, which either increase the fruit in size, or surmount it, or are adherent to it.
m 1. Pappus.
m 2. The calyptra of Mosses.
n. The pericarpium; comprehending all its species, from the simple caryopsis of Grasses.
n 1. Pericarpium open.
n 2. A dissepiment.
n 3. Valves.

n 4. An operculum.
n 5. The peristomum of Mosses.
n 6. The placenta. (Receptacle of the seeds of Gærtner.)
n 7. Funiculus umbilicalis.
n 8. The strophiola, or Caruncula umbilicalis.
n 9. Arillus.
o. The seed.
o 1. Wing of the seed.
o 2. Coma of the seed; in Asclepiadaceæ and Epilobium.
o 3. Integument of the seed.
o 4. Albumen. (Perisperm of Jussieu; Endosperm of Richard.)
o 5. Vitellus; in Zingiberaceæ and Nymphæa.
p. The embryo.
p 1. Cotyledon.
p 2. Plumula.
p 3. Radicle.
q. A leaf.
q 1. The petiole.
q 2. A stipula.
r. Portion of the stem or scape.
s. Inflorescence; comprehending all the species except the two following, s 1. and 2.
s 1. A compound flower.
s 2. The locusta of a Grass (either one-flowered or many-flowered.)
t. The involucrum of an umbel, or a head.
t 1. The involucrum of a compound flower. (Calyx communis of Linnæus.)
t 2. Glume of Grasses. (Calyx of Linnæus.)
t 3. Outer calyx of Malvaceæ, Dipsaceæ, Brunoniaceæ.
t 4. Involucrum of Ferns. (Indusium of Swartz.)
t 5. Bracteæ.
t 6. Scales of a catkin.
t 7. Paleæ.
t 8. The paraphyses of Mosses.
t 9. The calyptra when formed of connate bracteæ.
u. Receptacle of a single flower.
u 1. Common receptacle either of a compound flower, a catkin, or a head.
* Placed under one of the above (thus t_*^4), shows that a part is expanded, or opened, by force.
† Indicates a vertical section (used thus, $t\dagger^4$).
⁘ Indicates a transverse section (used thus, $t\therefore^4$).

EXPLANATION OF THE PLATES.

N.B. All the figures in the plates, of which the following is an explanation, are more or less magnified: the drawings from which they have been prepared are in all cases original, except where it is stated to the contrary.

PLATE I.

Fig. 1. A small portion of a section of the cellular tissue of the pith of Calycanthus floridus, showing the pore-like spots upon the membrane.

Fig. 2. A section of the leaf of Lilium candidum ; after A. Brongniart : *a*, epidermis of the upper surface ; *b*, ditto of the lower surface ; *c*, stomates cut through in different directions ; these last are seen to open into cavities in the parenchyma ; *d*, upper layer of parenchyma ; *e*, intermediate ditto ; *f*, lower ditto.

Fig. 3. Cubical cellular tissue, passing gradually into prismatical, from the stem of the gourd, cut vertically ; after Kieser.

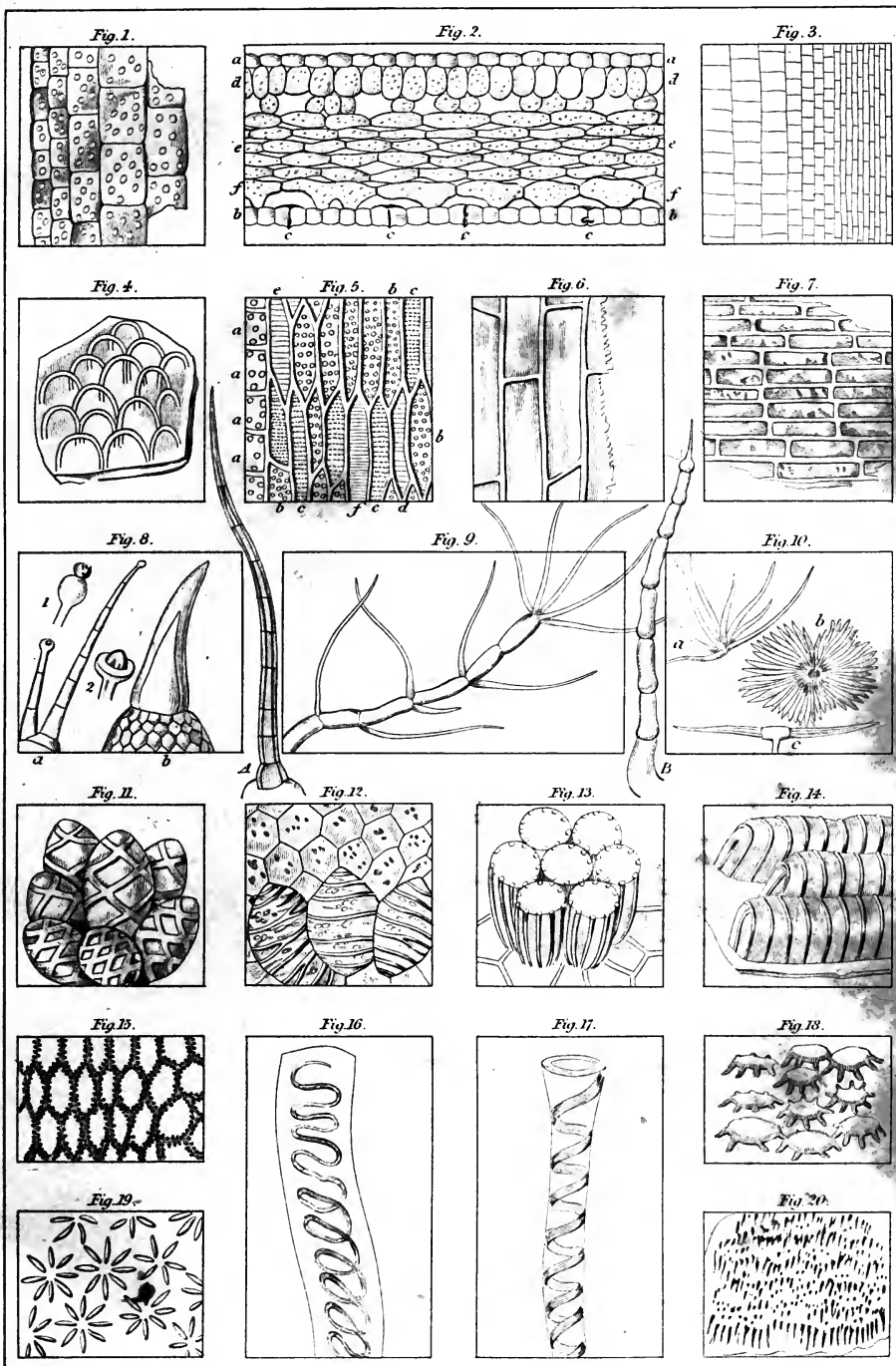
Fig. 4. Fibres forming arches in the endothecium of Linaria Cymbalaria ; after Purkinje.

Fig. 5. Fusiform cellules in the wood of a young branch of Viscum album ; after Kieser : *a*, common hexagonal cells of the pith, with grains of amydon sticking to their sides ; *b*, fusiform cellules, considered by Kieser to be pierced with holes ; *c*, other cells of the same figure, with lines of dots spirally arranged on the membrane ; *d*, others, in which the dots are run into lines ; *e*, *f*, others, in which the cellules have all the appearance of short spiral vessels. Kieser considers these not as spiral vessels, but as cellules of a peculiar kind, replacing spiral vessels in the Viscum.

Fig. 6. A portion of the cuticle of Billbergia amœna, with the membrane torn on one side, showing that it does not tear with an even edge, but breaks into little teeth.

Fig. 7. Muriform cellular tissue, forming the medullary processes of Platanus occidentalis. Each cellule contains particles of brownish matter of very irregular size and form.

Fig. 8. *a*, Glandular hairs of the peduncle of Primula sinensis ; 1. the glandular apex more highly magnified, with a particle of the viscid secretion of the species on its point ; 2, the apex of another hair, showing that the end is open, a conical piece of the viscid secretion lying in the orifice ; *b*, a hair



J.L. del.

S. Watts sculp.

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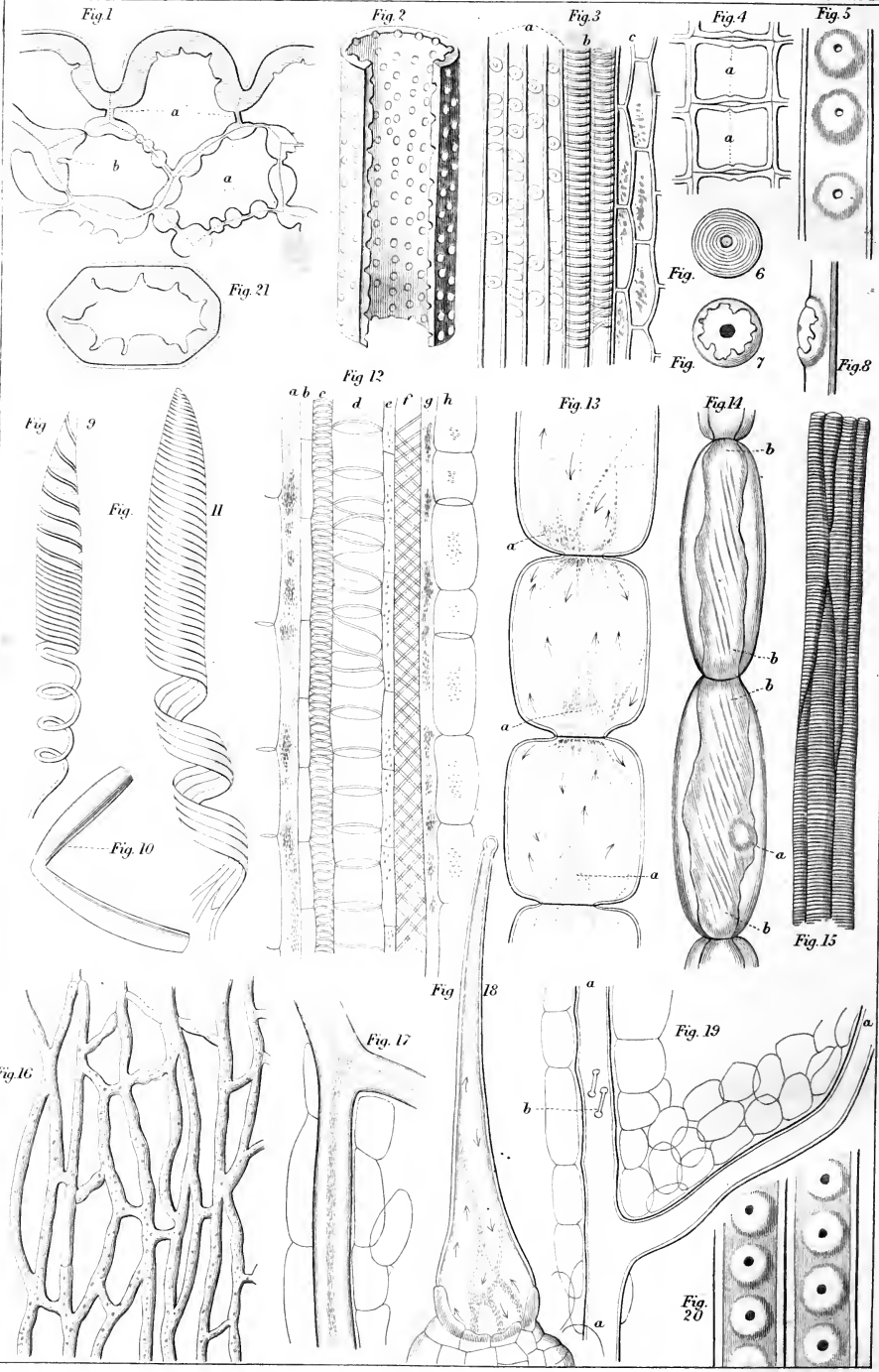

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of Dorstenia, showing the cellular base from which it arises, and that it consists of a single hollow conical curved cell.

Fig. 9. A branched hair from the cilia of the leaf of a species of Verbascum.

Fig. A. A simple coloured hair in Dichorizandra rufa.

Fig. B. A hair with tumid articulations from the leaf of Gesneria tuberosa.

Fig. 10. *a*, Stellate hairs from the leaf of a species of Hibiscus; *b*, a scale of the calyx of Elæagnus argentea; *c*, a hair of Chrysophyllum Cainito.

Fig. 11. Reticulated cellular tissue from the testa of Maurandya Barclayana.

Fig. 12. Spiral oblong cellules lying among the parenchyma of the leaf of Oncidium altissimum.

Fig. 13. Deep columnar cellules, with parallel fibres, from the endothecium of Calla æthiopica, the top of each cell being flat; after Purkinje.

Fig. 14. Arched fibres, connected by a membrane, in the endothecium of Nymphæa alba; after Purkinje.

Fig. 15. Flat oval cellules, with marginal incisions, in the endothecium of Phlomis fruticosa; after Purkinje.

Fig. 16. One of the elastic fibres upon the testa of Collomia linearis, unrolled spirally, and lying within its mucous sheath: magnified 500 times.

Fig. 17. A part of one of the elaters of a Jungermannia, showing a broad spiral fibre loosely twisted inside a transparent tubular membrane, with a dilated thickened mouth.

Fig. 18. Convex membranes, with lateral radiating fibres, forming together imperfect cells, in the endothecium of Veronica perfoliata; after Purkinje.

Fig. 19. Radiating fibres, in the place of cellules, in the endothecium of Polygala Chamæbuxus; after Purkinje.

Fig. 20. Prismatical depressed cells, with straight fibres on the walls, from the endothecium of Polygala speciosa; after Purkinje.

PLATE II.

Fig. 1. A section of pitted cellular tissue, showing on one side the matter of lignification separate from the elementary membrane; in the lines where the cells unite this is not shown, the membrane being so thin as to be inappreciable: *a a a* are pits in the sides of cells, corresponding with similar pits in the neighbouring cells; *b* shows that the pits are sometimes depressions without anything to answer to them on the opposite side.

Fig. 2. An ideal figure of part of a tube of bothrenchyma, showing that the apparent holes are mere pits in the interior.

Fig. 3. A section of coniferous wood: *a*, glandular pleurenchyma; *b*, spiral vessels; *c*, prismatical parenchyma, containing chlorophyll.

Fig. 4. A transverse section of two complete tubes of glandular pleurenchyma, to show that the glands are thin spaces in the sides of contiguous tubes, through which light passes in the direction of *a a*.

Fig. 5. A front view of coniferous glands in a young state.

Fig. 6. A very highly magnified view of such glands, showing that their surface is marked by concentric circles.

Fig. 7. A front view of a coniferous gland, partially covered by the matter of lignification.

Fig. 8. A profile view of the same.

Fig. 9. A simple or one-threaded spiral vessel, partly unrolled, with its termination.

Fig. 10. A bent portion of the spire of the latter, to show that elementary fibre is cylindrical.

Fig. 11. A compound or many-threaded spiral vessel, partly unrolled, with its terminations.

Fig. 12. A longitudinal section of a portion of a stem, showing various kinds of tissue : *a* and *g*, tubes of cinenchyma or laticiferous tissue ; *b*, cylindrical parenchyma ; *c*, an annular duct ; *d*, an annular duct of larger size, with its spires more broken ; *e*, cylindrical parenchyma containing amylaceous granules ; *f*, a reticulated duct ; *h*, oblong parenchyma containing amylaceous granules.

Fig. 13. Joints of a hair, showing the capillary branches from the cytoblast in which circulation takes place ; *a*, cytoblasts ; the arrows indicate the direction of the currents.

Fig. 14. Two joints of a hair of Tradescantia in a dead state, to show the collapsed appearance of the protoplasm enclosed within the external cavity or cell wall, and over which the currents of motion are maintained ; *a*, a cytoblast.

Fig. 15. A bundle of closed ducts from the stem of a Lycopodium ; after a preparation by Mr. Griffith. Here is seen the manner in which such vessels are packed *in situ*, together with their terminations.

Fig. 16. A portion of cinenchyma, or laticiferous tissue, from the stipule of the Ficus elastica, showing the anastomoses ; after Schultz.

Fig. 17. One of the anastomoses of cinenchyma, surrounded by thin-sided oblong parenchyma.

Fig. 18. A stinging hair, in which circulation is going on, the direction of the currents being indicated by arrows.

Fig. 19. An anastomosis in the cinenchyma of a Euphorbia, with two of the double-headed bodies supposed to be amylaceous ; *a a* represent the mouths of the cinenchyma.

Fig. 20. Glandular pleurenchyma of Sphærostema propinquum.

PLATE III.

Fig. 1. A cluster of six-sided air-cells from the stem of Limnocharis Plumieri ; they are formed entirely of prismatical cells ; *a a*, partitions dividing the air-cells in two.

Fig. 2. A partition or diaphragm of the last-mentioned plant, showing the open passages that exist at the angles of the cells. When dry, the rims of the passages are dark, as at *a* ; when immersed in water, the dark rim disappears, and the whole partition has the uniform appearance of *b*.

Fig. 3. A portion of the epidermis, and a stoma, of the leaf of Oncidium altissimum ; *a*, the stoma, formed of two parallel glands or cells, which open by curving outwards. In this plant the stomata are very minute and few ; on the membrane of each mesh of the epidermis are found sticking from four to six spherical semi-transparent green globules.

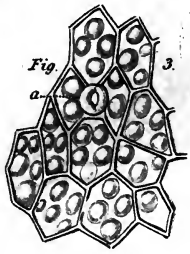
Fig. 3.
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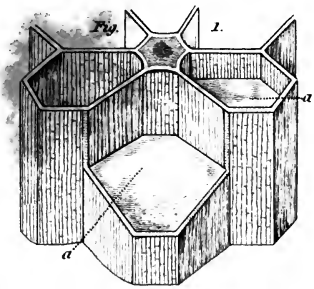
Fig. 1.
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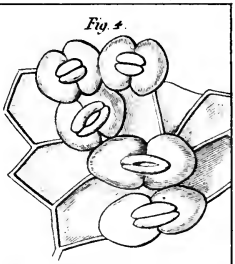
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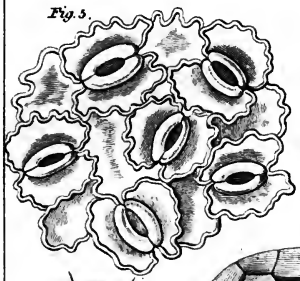
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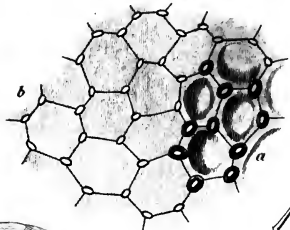
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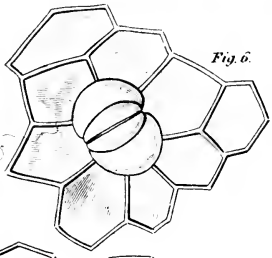
Fig. 2.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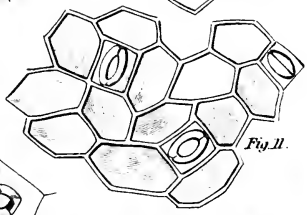
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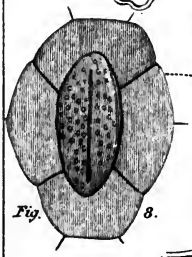
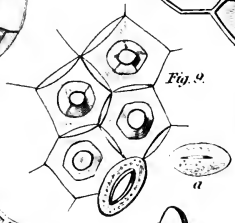


Fig. 8.

Fig. 7.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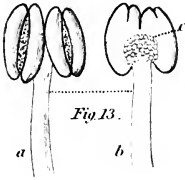
Fig. 13.
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b
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a
Fig. 14.

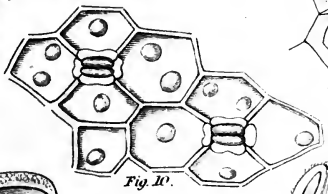
Fig. 10.

Fig. 12.

Fig. 16.

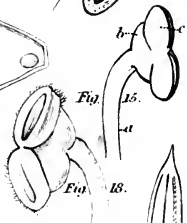
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Fig. 18.

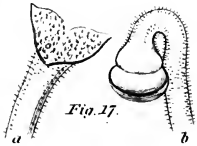
Fig. 17.
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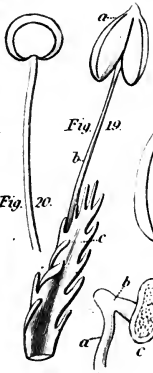
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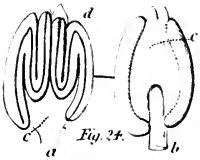
d
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Fig. 24.

Fig. 27.

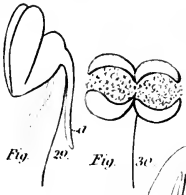
Fig. 29.
Fig. 30.

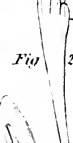
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Fig. 25.

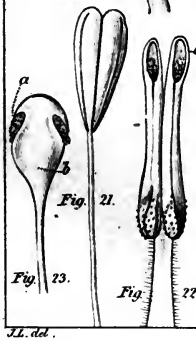
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Fig. 21.
Fig. 23.
Fig. 22.

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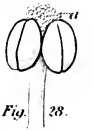
Fig. 26.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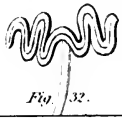
Fig. 32.

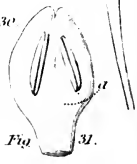
a
Fig. 31.

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Fig. 4. Stomata of Strobilanthes Sabiniana. They are very large, and crowded together in an irregular manner.

Fig. 5. Ditto of Croton variegatum: this is an instance of an epidermis with sinuous lines. The orifice of each stoma is closed up with brownish matter.

Fig. 6. A stoma of Canna iridiflora.

Fig. 7. A cavity beneath the epidermis, in the parenchyma of Begonia sanguinea seen from the inside, so that the epidermis is farthest from the eye. It is divided by sub-cylindrical cellules into five spaces, in each of which there lies a stoma.

Fig. 8. One of the stomata of the same, more magnified, and showing that the medial line does not touch either end, and that the cavity of the stoma is filled with granular matter.

Fig. 9. Stomata of the under side of the leaf of Caladium esculentum, with a portion of epidermis. These appear to be somewhat angular cellules, occupying the centre of every area of the epidermis. The stoma consists of an oval space, in the centre of which is a narrow cleft, with a border distinctly coloured orange or brownish, and having no communication with the circumference; the space between the cleft and the latter filled with a pale green granular substance. The cleft is sometimes seen closed, as at *a*, and then there is scarcely any appearance of a border.

Fig. 10. Epidermis and stomata of Yucca gloriosa; the latter lie in square areolæ, and consist of two parallelograms lying parallel with each other. Small spheroidal bodies, having a luminous appearance under the microscope, stick here and there to the inside of the epidermis.

Fig. 11. Stomata of Limnocharis Plumieri. These also lie in square areolæ, but they have the ordinary structure: they are found in different degrees of openness, or even quite closed, upon a small piece of the same specimen.

Fig. 12. Stamen of Lemna trisulca: anther bursting vertically.

Fig. 13. Stamen of Polygonum Convolvulus: *a*, seen in front; *b*, from behind; *c*, the connectivum of the anther.

Fig. 14. Stamen of Corræa alba: *a*, seen in front; *b*, from behind.

Fig. 15. Stamen of Stachys sylvatica: *a*, filament; *b*, connectivum; *c*, anther, its lobes separated at the base by the connectivum.

Fig. 16. Anther of Alchemilla arvensis; one-celled, and bursting transversely.

Fig. 17. Stamen of Scrophularia chrysanthemifolia: *a*, part of the filament, and the anther, which is one-celled, after bursting; *b*, the same, before the dehiscence of the anther.

Fig. 18. Anther of Lamium album; its lobes, as in fig. 16., separated at their base by the large connectivum.

Fig. 19. Stamen of a species of Zygophyllum: *a*, the anther; *b*, the filament; *c*, the scale to which the filament adheres.

Fig. 20. The one-celled anther and filament of Callitriche.

Fig. 21. The stamen of Sparganium ramosum.

Fig. 22. The stamen of Vaccinium amœnum: *a*, the pores by which the anther bursts.

Fig. 23. The anther of Begonia Evansiana: *a*, the oblique immersed cells; *b*, the connectivum.

Fig. 24. Anther of Cucumis sativa: *a*, seen from the front; *b*, from behind; *c*, the connectivum; *d*, the sinuous lobes of the anther.

Fig. 25. Stamen of Hermannia flammea: *a*, filament; *b*, scale to which the latter has grown.

Fig. 26. Halved stamen of Synaphea dilatata; after Ferdinand Bauer: *a*, filament; *b*, connectivum; *c*, single lobe of the anther after bursting.

Fig. 27. Stamen of Eupomatia laurina, after the same.

Fig. 28. Stamen of Cephalotus follicularis, after the same: *a*, a granular connectivum.

Fig. 29. Stamen of Pterospora Andromedea: *a*, an appendage of the anther.

Fig. 30. Stamen of Securinega nitida: the cells opening transversely.

Fig. 31. Stamen of Chloranthus monostachys: *a*, connectivum.

Fig. 32. Stamen of Eriodendron Samaüma; after Von Martius: anther sinuous and one-celled.

PLATE IV.

Figs. 1, 2, 3. Different views of the stamens and stigma of Stylidium violaceum; after Ferdinand Bauer: *a a*, anthers; *b*, a column formed by the union of their filaments; *c*, a cup-like disk, consisting of the flattened and united apices of the filaments; *d*, the stigma, the style of which is united with the column of filaments through its whole length. Fig. 1. The anthers when burst, seen in front; fig. 3. the same, from behind; fig. 2. the anthers pushed aside, so as to show the stigma.

Fig. 4. Stamen of Rhynchanthera cordata; after Von Martius: *a*, a minute membrane that separates the filament *d* from the elongated connectivum *c*; *b*, the attenuated beak-like apex of the anther, opening by a single pore at the point.

Fig. 5. Stamen of Lasiandra Maximiliana; after Von Martius: *a*, dilated bases of the two cells of the anther; *b*, pore at the apex, through which the pollen is discharged.

Fig. 6. Stamen of Glossarrhen floribundus; after Von Martius: *a*, a dilated petaloid connectivum, to the face of which the lobes of the anther adhere; *b*, the filament.

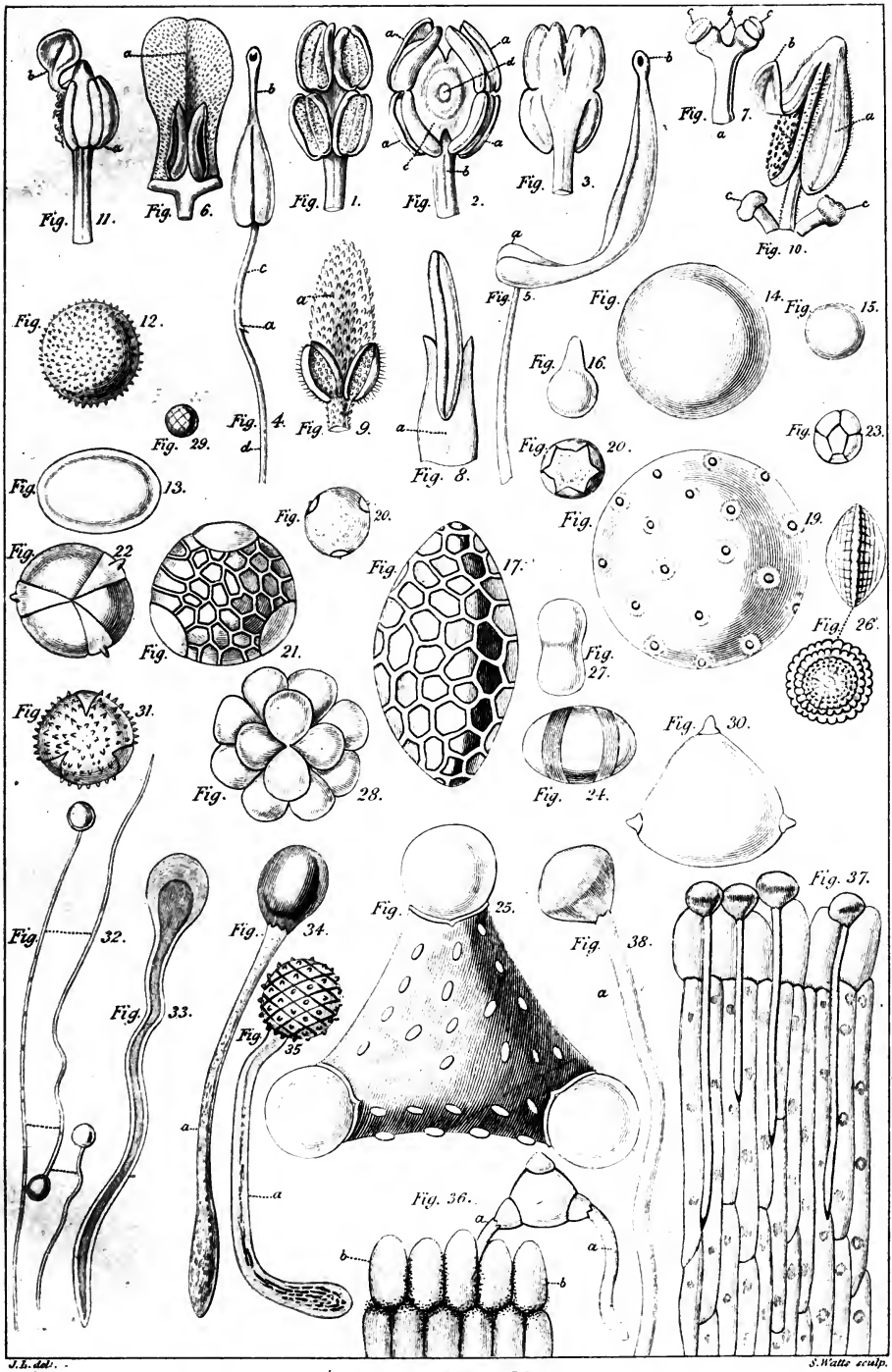
Fig. 7. Stamen of Lacistema pubescens; after Von Martius: *a*, filament; *b*, forked connectivum; *c c*, separate lobes of the anther.

Fig. 8. Stamen of Gomphrena leucocephala; after Von Martius: *a*, broad dilated two-toothed filament, bearing a linear one-celled anther.

Fig. 9. Stamen of Humirium floribundum; after Von Martius: *a*, a large tuberculated petaloid connectivum.

Fig. 10. Stamen of a species of Cryptocarya, from Chili, in which the anther opens, as in other Laurineæ, by valves that roll back when they separate: *a*, one lobe of the anther, with the valve not separated; *b*, the other lobe, with the valve in the act of rolling back; *c c*, abortive stamens, under the form of glands.

Fig. 11. Stamen of Berberis vulgaris, exhibiting the same phenomenon: *a*, valve closed; *b*, valve separated and recurved.



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S. Watts sculp.

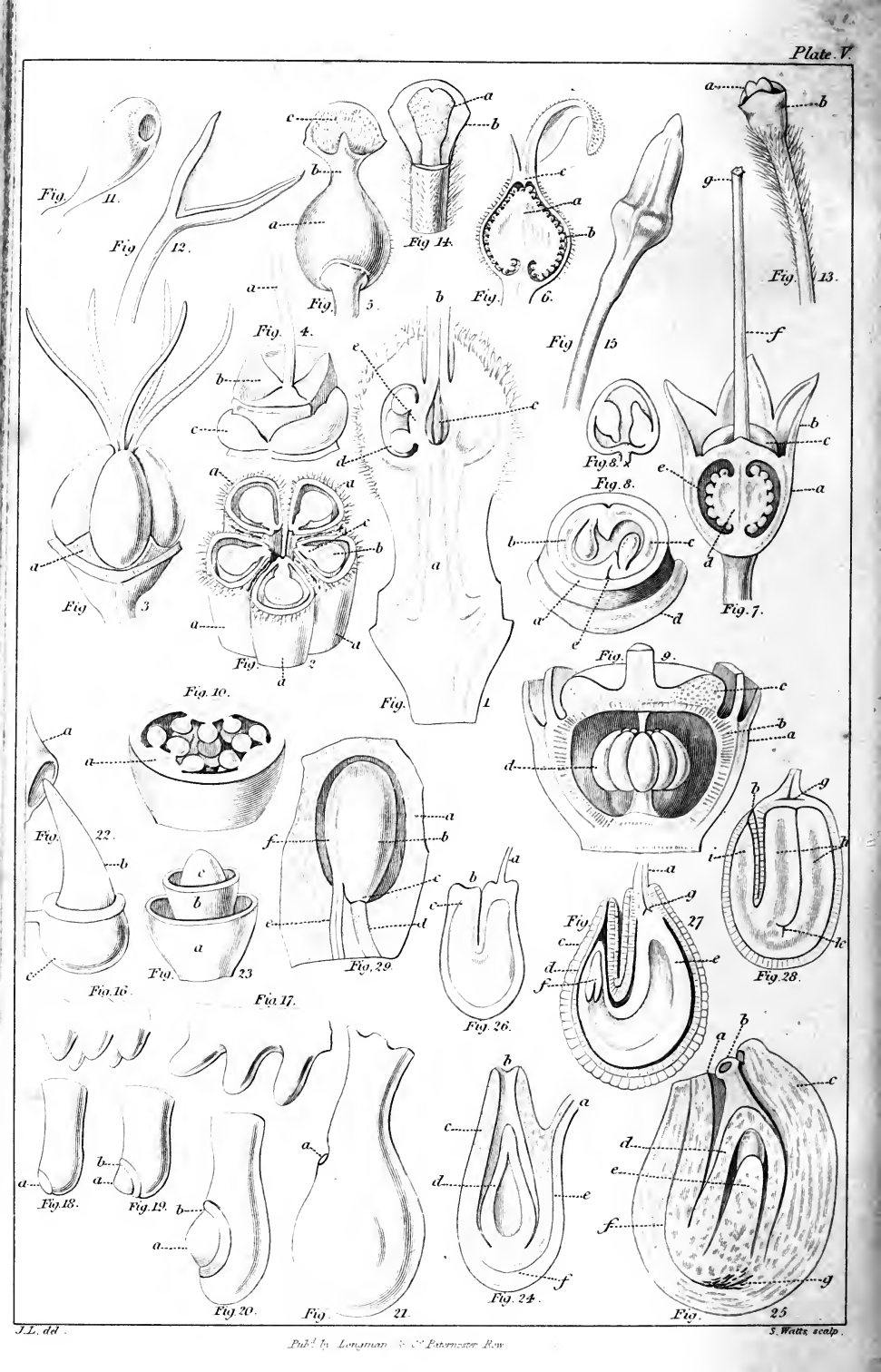
Fig. 11.
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Fig. 24.
Fig. 25
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S. Watts, scalp.
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*** *All the following figures of pollen are taken, with scarcely any alteration, from Purkinje, and are drawn to the same scale, so that their relative sizes are shown.*

Fig. 12. Pollen of Stratiotes aloides.
13. Calla æthiopica.
14. Elymus sabulosus.
15. Avena latifolia.
16. Scirpus romanus.
17. Pancratium declinatum.
18. Populus alba.
19. Mirabilis Jalapa.
20. Urtica dioica.
21. Armeria fasciculata.
22. Plumbago rosea.

Fig. 23. Pollen of Cineraria maritima.
24. Salvia interrupta.
25. Stachytarpheta mutabilis.
26. Polygala spinosa.
27. Heracleum sibiricum.
28. Acacia lophantha.
29. Iresine diffusa.
30. Fuchsia coccinea.
31. Scorzonera radiata.

Fig. 32. Grains of pollen of Gesnera bulbosa emitting their tubes, magnified 180 times. The tube is of extreme tenuity, and may be withdrawn from the stigmatic tissue with great facility. Masses of granular matter may be seen descending the tubes at irregular intervals.

Fig. 33. A grain of pollen of the same plant, with its tube magnified 500 times: this shows that the tube is an extension of the outer membrane of the grain of pollen, if the latter was coated by more than one. The granular matter is seen passing down the tubes, and quitting the grain of pollen, which finally becomes a transparent empty vesicle.

Fig. 34. Grain of pollen of Datura Stramonium, emitting its tube; after Brongniart: *a*, pollen-tube.

Fig. 35. Grain of pollen of Ipomœa hederacea, emitting its tube; after Brongniart: *a*, pollen tube.

Fig. 36. Mode in which the pollen acts upon the stigma in Œnothera biennis: *a a*, pollen tubes; *b b*, tissue of the stigma into which these tubes penetrate; after Brongniart.

Fig. 37. Mode in which the pollen acts upon the stigma in Antirrhinum majus; after Brongniart. The pollen sticks to the surface of the stigma, and the tubes plunge down between the utricles of cellular tissue, of which the stigma consists.

Fig. 38. A grain of pollen of the same plant with its tube, more highly magnified: *a*, the pollen tube.

PLATE V.

Fig. 1. Vertical section of the ovarium of Dictamnus albus: *a*, gynophorus, or elongated base of the ovarium; *b*, base of the style; *c*, cavity where the carpella have not united; *d*, cell; *e*, placenta, with ovula attached to it.

Fig. 2. Transverse section of the same in a more advanced state, where the

carpella are beginning to separate: *a a*, carpella; *b*, an ovulum cut through; *c*, placenta.

Fig. 3. Pistillum of Coriaria myrtifolia; consisting of five carpella, each bearing a single linear stigma, and collected round a common elevated axis, the base of which is seen at *a*.

Fig. 4. Ovarium of Lamium album: *a*, base of the style; *b*, carpella pressed together into a square concave body; *c*, fleshy lobed disk.

Fig. 5. Pistillum of Pinguicula vulgaris: *a*, ovarium; *b*, style; *c*, stigma, consisting of two very unequal lobes.

Fig. 6. A vertical section of the same: *a*, the central free placenta; *b*, ovula; *c*, point where the placenta is connected, before fertilisation, with the stigmatic tissue.

Fig. 7. A perpendicular section of the pistillum of Vaccinium amœnum; *a*, inferior ovarium combined with the tube of the calyx; *b*, limb of the calyx; *c*, epigynous disk; *d*, placenta; *e*, ovula; *f*, style; *g*, stigma.

Fig. 8. A transverse section of the ovarium of Hydrophyllum canadense, showing its remarkable placentation; *a*, wall of the ovarium; *b*, left placenta; *c*, right placenta; *e*, one of their points of union, the other is seen on the opposite side; *d*, a fleshy secreting annular disk. In this case, two placentæ grow up face to face from the base of the ovarium, and gradually unite at their edges (*e*), enclosing the ovula within the cavity they thus form; this is proved by Nemophila, in which the placentation is the same, except that the placentæ are always distinct from each other; one of these placentæ, the ovuliferous face turned towards the eye, is represented at fig. 8.

Fig. 9. A perpendicular section of the inferior ovarium of Thamnea uniflora; after A. Brongniart: *a*, tube of the calyx; *b*, wall of the ovarium; *c*, epigynous disk; *d*, ovula collected round a columnar placenta.

Fig. 10. Transverse section of the ovarium of Viola tricolor, showing its parietal placentation: *a*, one of the three placentas.

Fig. 11. Stigma of the same plant, which is inflated and hollow, with an orifice obliquely situated at its apex.

Fig. 12. Bifid stigma of Chloanthes Stœchadis; after Ferdinand Bauer.

Fig. 13. Hairy apex of the style and stigma, with its indusium, of Brunonia australis; after Ferdinand Bauer: *a*, stigma; *b*, indusium.

Fig. 14. The same, divided perpendicularly; *a*, stigma; *b*, indusium.

Fig. 15. Stigma of Banksia coccinea, with a part of the style; after Ferdinand Bauer.

Fig. 16. The earliest state of the ovula of Cucumis Anguria; this, and the succeeding figures, to 25 inclusive, are after Mirbel.

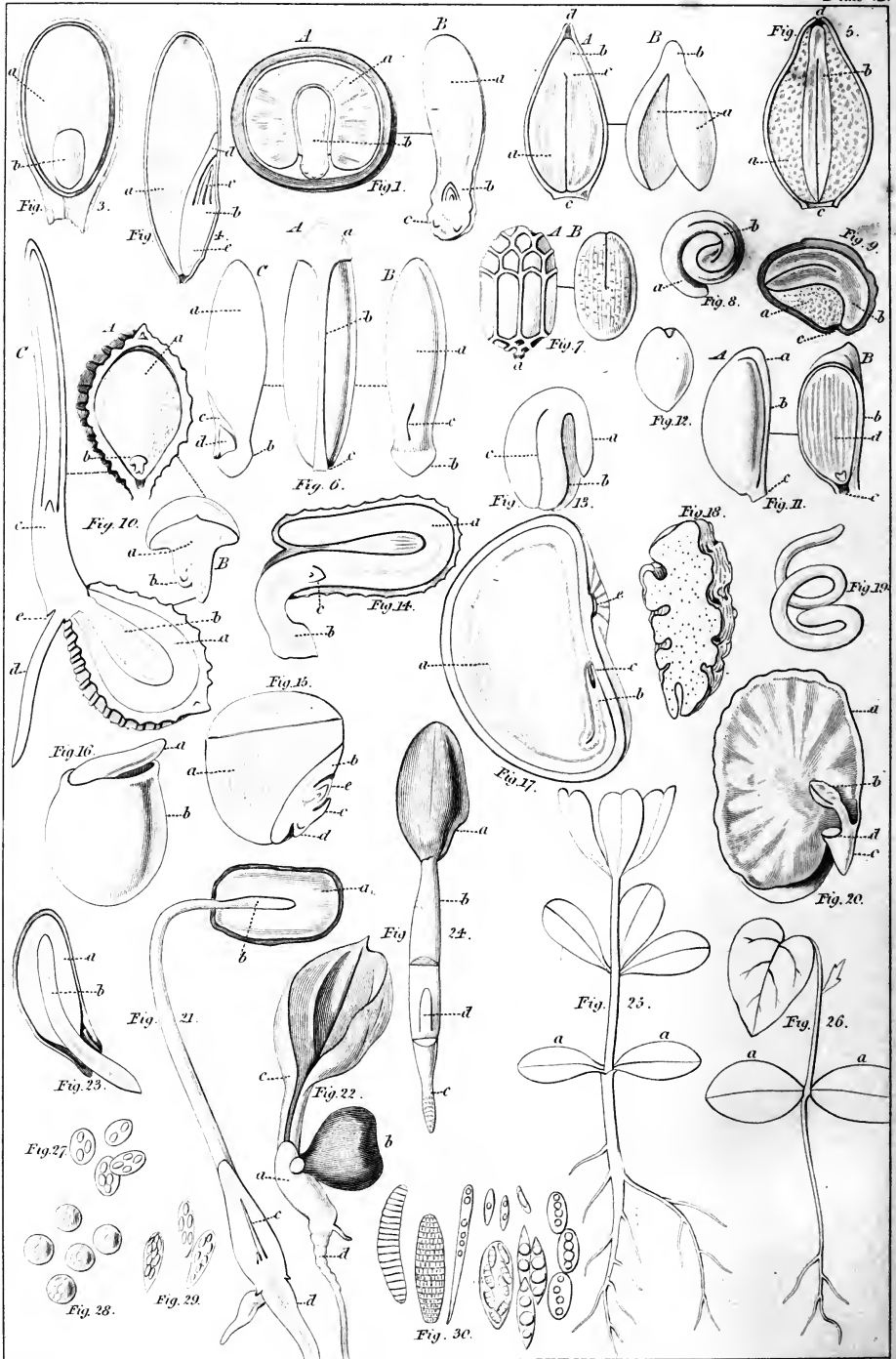
Fig. 17. Three of these ovules in a more advanced state.

Fig. 18. An ovulum at the period when the apex of the nucleus (*α*) is just appearing through the primine. The foramen has already become oblique with respect to the apex of the ovulum.

Fig. 19. An ovulum of the same, at the period when the secundine is appearing through the foramen: *a*, nucleus; *b*, border of secundine; the nucleus is now more oblique than before.

Fig. 20. An ovulum of the same, at a subsequent period, but still long before the expansion of the flower; the several parts are more developed; the nucleus, which at first was terminal, has now become lateral, and is

Plate VI.



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evidently turning towards the base of the ovulum: *a*, nucleus; *b*, border of secundine.

Fig. 21. An ovulum of the same, after fertilisation. In the interval between this state and the last, the primine has grown over the secundine and nucleus; the apex of the latter has turned completely to the base of the ovulum; and the foramen is contracted into the little perforation at *a*.

Fig. 22. Ovulum of Euphorbia Lathyris, in a very young state, long before the expansion of the flower: *a*, kind of cap projecting from the wall of the ovarium, and into which the apex of the nucleus (*b*) is inserted: this hood finally closes over the foramen, into which it protrudes as the nucleus retreats; *c*, the primine; the secundine is a similar cap included within the primine.

Fig. 23. Very young ovulum of Ruta graveolens: *a*, the primine; *b*, the secundine; *c*, the nucleus. In the end, the primine extends, contracts at its foramen, and closes over the secundine and nucleus.

Fig. 24. Vertical section of an ovulum of Alnus glutinosa: *a*, the umbilical cord; *b*, foramen; *c*, primine (and secundine perhaps united with it); *d*, nucleus; *e*, vessels of the raphe; *f*, place of the chalaza.

Fig. 25. An oblique vertical section of the fertilised ovulum of Tulipa Gesneriana: *a*, foramen of the primine (or Exostome); *b*, foramen of the secundine (or Endostome); *c*, primine; *d*, secundine; *e*, nucleus, its apex concealed within that of the secundine; *f*, vessels of the raphe; *g*, place of the chalaza.

Fig. 26. Ovulum of Lepidium ruderale; after A. Brongniart: *a*, umbilical cord; *b*, foramen; *c*, point of the nucleus seen through the primine and secundine.

Fig. 27. Half-ripe seed of the same, cut through perpendicularly; after Brongniart: *a*, the umbilical cord; *b*, foramen; *c*, primine; *d*, secundine; *e*, nucleus; *f*, embryo partially formed, its radicle pointing to the foramen; *g*, the point where the nourishing vessels of the placenta expand (the chalaza).

Fig. 28. A perpendicular section of the ripe seed of the same; after A. Brongniart. The primine and secundine are consolidated, and the nucleus is entirely absorbed by the embryo. *a*, Umbilical cord; *b*, foramen, now become the micropyle; *g*, chalaza; *h*, cotyledons of the embryo; *i*, radicle; *k*, plumula.

Fig. 29. Mode of fertilisation in Cucurbita Pepo; after Adolphe Brongniart: *a*, a portion of the placenta; *b*, ovulum; *c*, its foramen; *d*, the bundle of stigmatic tissue through which the fertilising matter is conveyed, and to which the foramen is closely applied; *e*, the bundle of vessels that communicates with the umbilicus; *f*, the commencement of the raphe.

PLATE VI.

Fig. 1. A, Vertical section of the seed of Canna lutea: *a*, albumen; *b*, embryo. —B, Embryo extracted and divided vertically: *a*, cotyledon; *b*, plumula concealed within the embryo; *c*, radicle, with internal rudiments of roots.

Fig. 2. A, Vertical section of the seed of Myrica cerifera: *a*, cotyledons; *b*, radicle; *c*, plumula; *d*, remains of foramen; *e*, hilum.—B, Embryo extracted entire: *a*, cotyledons; *b*, radicle.

Fig. 3. Vertical section of the seed of Luzula campestris: *a*, albumen; *b*, embryo.

Fig. 4. Vertical section of the grain of Bromus mollis: *a*, albumen; *b*, embryo; *c*, its plumula; *d*, its cotyledon; *e*, its radicle, with internal rudiment of a root.

Fig. 5. Vertical section of the seed of Rheum rhaponticum: *a*, albumen; *b*, embryo; *c*, hilum; *d*, remains of foramen.

Fig. 6. A, Seed of Triglochin palustre: *a*, fungous chalaza; *b*, raphe; *c*, hilum. —B, Embryo of the same: *a*, cotyledon; *b*, radicle; *c*, fissure, within which the plumula lies.—C, The same halved vertically: *a*, cotyledon; *b*, radicle; *c*, fissure; *d*, plumula.

Fig. 7. A, Seed of a species of Begonia: *a*, hilum. — The dicotyledonous embryo.

Fig. 8. Coiled up embryo of Basella rubra: *a*, radicle; *b*, cotyledons.

Fig. 9. Vertical section of the seed of Mesembryanthemum crystallinum: *a*, albumen; *b*, radicle of the embryo.

Fig. 10. Anatomy of the grain, and germination of Scirpus supinus; after Richard.—A, Vertical section: *a*, albumen; *b*, embryo.—B, The embryo extracted, enlarged, and halved vertically: *a*, cotyledon; *b*, radicle.—C, The seed germinating and halved: *a*, albumen; *b*, cotyledon; *c*, plumula; *d*, young root; *e*, sheath of the latter.

Fig. 11. A, Seed of Ribes rubrum: *a*, chalaza; *b*, raphe; *c*, hilum.—B. The same, halved vertically, showing the minute embryo, with two spreading cotyledons lying at the base of the albumen: *b*, section of the raphe; *c*, hilum; *d*, albumen.

Fig. 12. Embryo of a species of Mammillaria; the cotyledons very small.

Fig. 13. Embryo of Geranium Robertianum: *a*, radicle; *b*, line of union of the two cotyledons; *c*, one of the plaits in the latter.

Fig. 14. Section of the seed of Alisma Damasonium; after Mirbel: *a*, cotyledon; *b*, radicle; *c*, plumula.

Fig. 15. Part of the seed of Olyra latifolia; after Richard: *a*, albumen; *b*, back cotyledon; *c*, front ditto; *d*, radicle; *e*, plumula.

Fig. 16. Embryo of Ruppia maritima; after Richard: *a*, plumula; *b*, cotyledon.

Fig. 17. Vertical section of the seed of Pekea tuberculosa; after Richard: *a*, radicle; *b*, collet; *c*, cotyledons.

Fig. 18. Embryo and ruminated albumen of Eupomatia laurina (a vertical section); after Ferdinand Bauer.

Fig. 19. Spiral twisted embryo of Cuscuta europæa.

Fig. 20. Half the embryo of a bean (Vicia Faba); after Mirbel: *a*, one of the cotyledons; *b*, plumula; *c*, radicle; *d*, scar from which the other cotyledon has been cut.

Fig. 21. Germination of Lachenalia serotina: *a*, albumen; *b*, cotyledon; *c*, plumula; *d*, radicle.

Fig. 22. Germination of Calla æthiopica; after Mirbel: *a*, exterior elongation of the cotyledon; *b*, seed; *c*, front leaf of the plumula; *d*, radicle.

Fig. 23. Germination of Allium Cepa : *a*, albumen ; *b*, embryo elongated beyond the testa.

Fig. 24. The same further advanced : *a*, seed ; *b*, base of the cotyledons ; *c*, radicle or young root ; *d*, plumula.

Fig. 25. Germination of Baptisia australis ; after De Candolle : *a a*, cotyledons.

Fig. 26. Germination of Cercis Siliquastrum ; after De Candolle : *a a*, cotyledons.

Fig. 27. Thecæ, or Sporangiola, of Erysiphe adunca ; after Greville.

Fig. 28. Sporules of Phascum crassinervium ; after Greville.

Fig. 29. Asci, or Thecæ, of Sphæria tubæformis ; after Greville.

Fig. 30. Thecæ of various Lichens ; after Von Martius.

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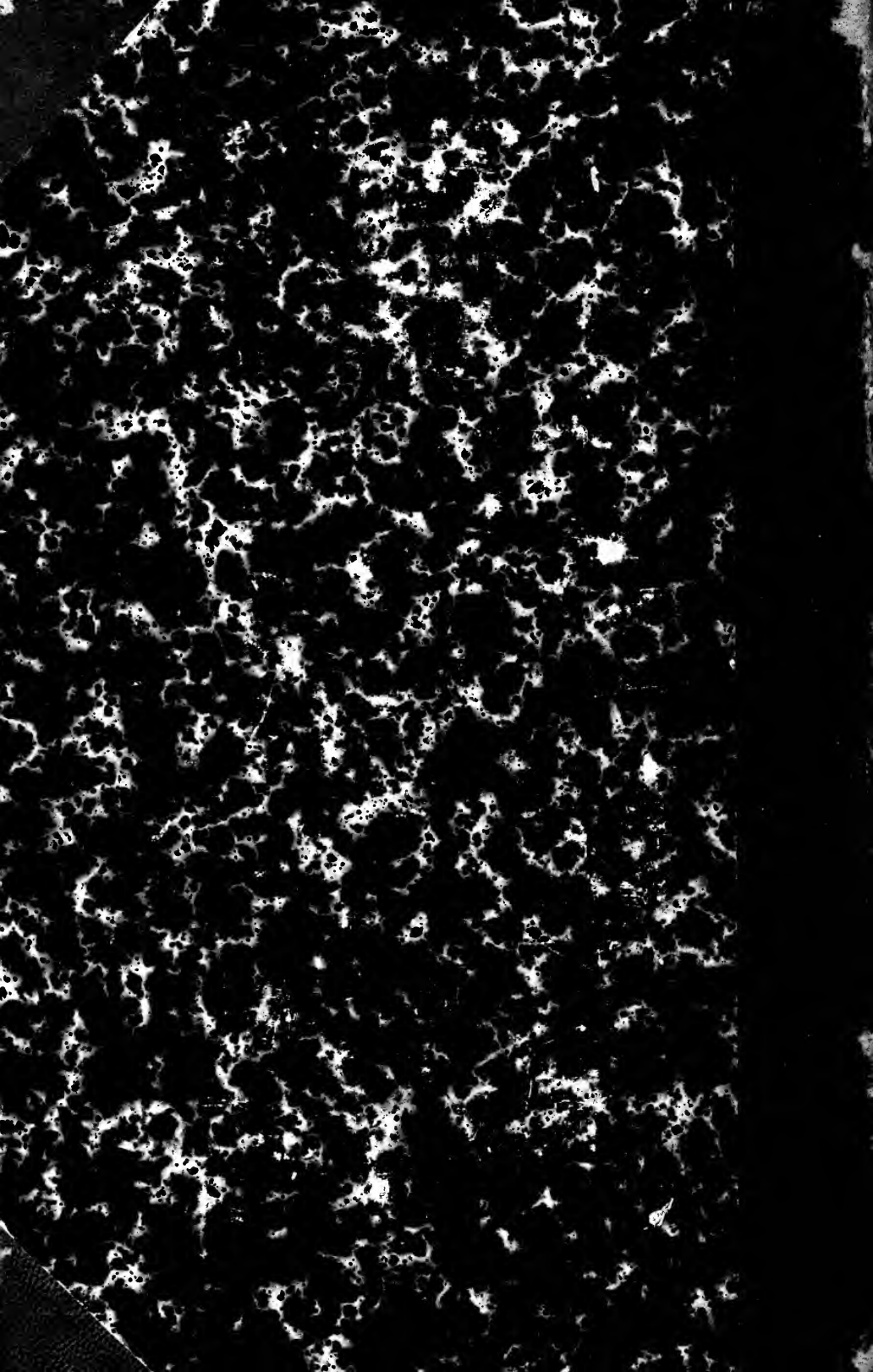
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